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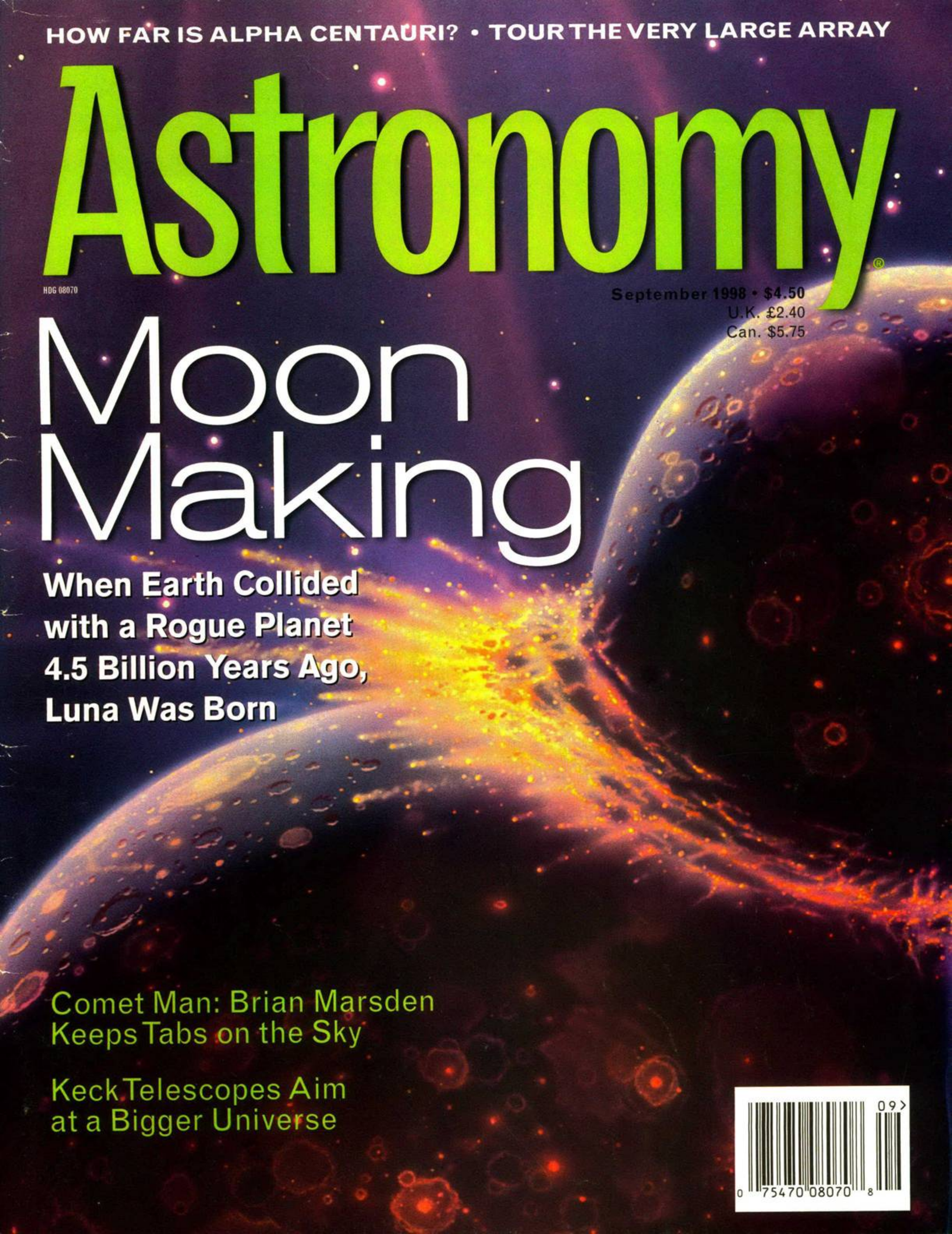

Moon Making

When Earth Collided with a Rogue Planet 4.5 Billion Years Ago, Luna Was Born

Comet Man: Brian Marsden Keeps Tabs on the Sky

Keck Telescopes Aim at a Bigger Universe

MEADE LX50

Advanced technology at the most affordable prices *ever.*

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- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four- speed (2x, 8x, 16x, 32x sidereal) dual-axis drive correction/microslewing system.

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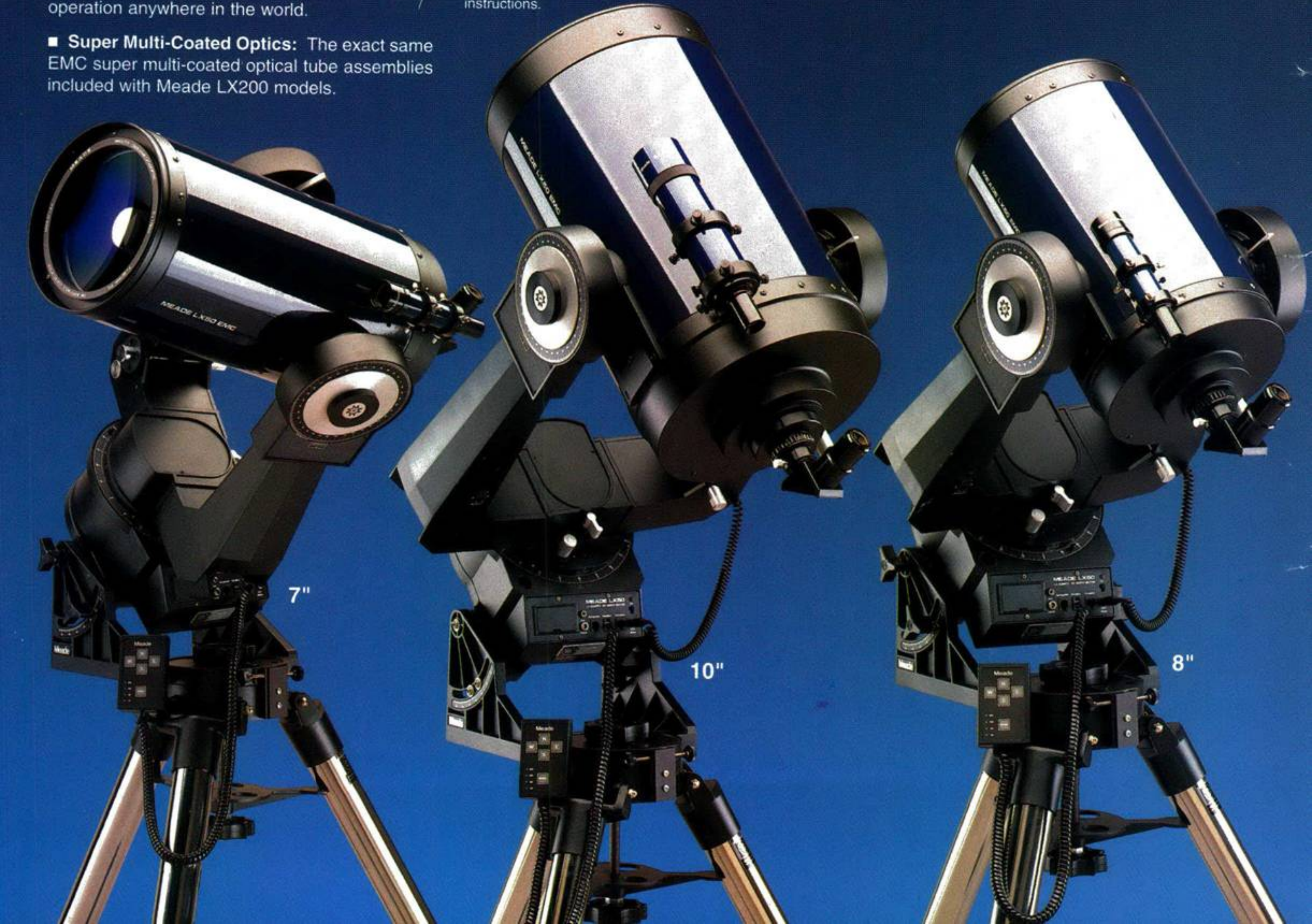
#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.



In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment specifications*:

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from *2x photo-guide*, to 32x image centering, to 8°/sec. slewing across *the sky, as well as 6 other dual-axis drive* speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

MEADE LX200

The largest-selling serious telescopes in the world.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain *optical tube assembly with EMC super multi-coatings;* heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating *instructions.*

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

Write, call, or fax Meade Instruments for your free copy of the 100-page Meade *General Catalog.*

Prices shown are suggested U.S. mail-order retail prices.

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September 1998 • Vol. 26, No. 9

Astronomy®

COVER ART: Joe Tucciarone

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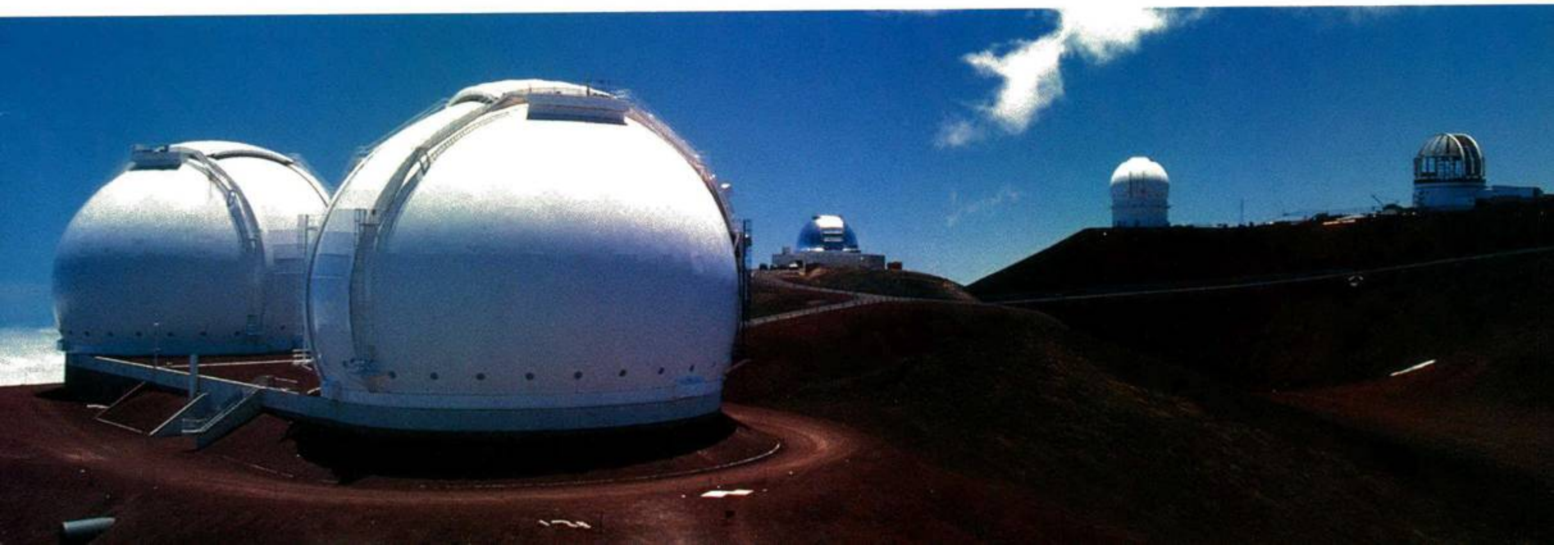

BY BONNIE BILYEU GORDON

Seeking Life

The martian meteorite that hinted at off-Earth life has unleashed new energy in a worldwide watch for extraterrestrials of even the tiniest sort. And more recent discoveries suggest that water, the signature of life as we know it, exists in every corner of the universe. Even NASA, ordinarily conservative on the topic, has recently endorsed life with the launch of an Astrobiology Institute as a key component in its Origins Program.

Biologists, chemists, and geologists from 11 institutions will join forces with astronomers in an effort to seek life in space, and they will exchange information across the fiber-optic cables of the Next Generation Internet, according to NASA Administrator Daniel Goldin. The team will share $9 million in funding in 1999 and $20 million in 2000. Among other things, team members will try to find out how and where habitable planets form, and they will study the Earth-bound evolution of ancient metabolisms, multicellular animals, and organisms in such extreme environments as hydrothermal vents. The team, chosen from 53 proposals, includes researchers from Harvard, University of California at Los Angeles, Scripps Research Institute, Carnegie Institution, Woods Hole Marine Biological Laboratory, and Ames Research Center, which will serve as the institute's headquarters.

Tracy Staedter

Photos by *Astronomy*/Jim Forbes

We hope they find any old sign of life, and when they do, we hope they share that find with the rest of us. No holding it up in *The X-files.*

Our own team here at *Astronomy* magazine is about to undergo some change. Tracy Staedter is returning to *Astronomy* as an associate editor. She worked with the magazine for six and a half years before moving to *Earth* magazine, where she spent two years. In addition to being a talented magazine writer and editor, Tracy assists in teaching communications courses at Alverno College and she is writing a children's book on rocks and minerals. She will be replacing Patti Kurtz, who has been an editor for two years. Homesick, Patti is returning with her two teenaged sons to Denver, Colorado.

Sarah Simpson is becoming copy editor of *Astronomy*, replacing Jeanette Brown, who will be attending graduate school at New York University. Sarah, the former copy editor of *Earth*, earned undergraduate degrees in both journalism and science at the University of Missouri. She loves, rock climbing, volleyball, stargazing and her dog, Frannie.

Sarah Simpson

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The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds*, just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

SPECIFICATIONS: ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions.

Net weight 9 lbs. **$595***

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*Suggested U.S. mail-order retail price.

New! ETX Field Tripod

The rigid, full-length ETX Field Tripod allows for standing or seated observations through the telescope. Micrometric controls in both azimuth and elevation-angle permit precise polar alignment of the telescope's fork mount for astronomical applications. For terrestrial observing, where altazimuth orientation is desirable, the tripod head tilts to 90°. *Net weight 11 lbs.*

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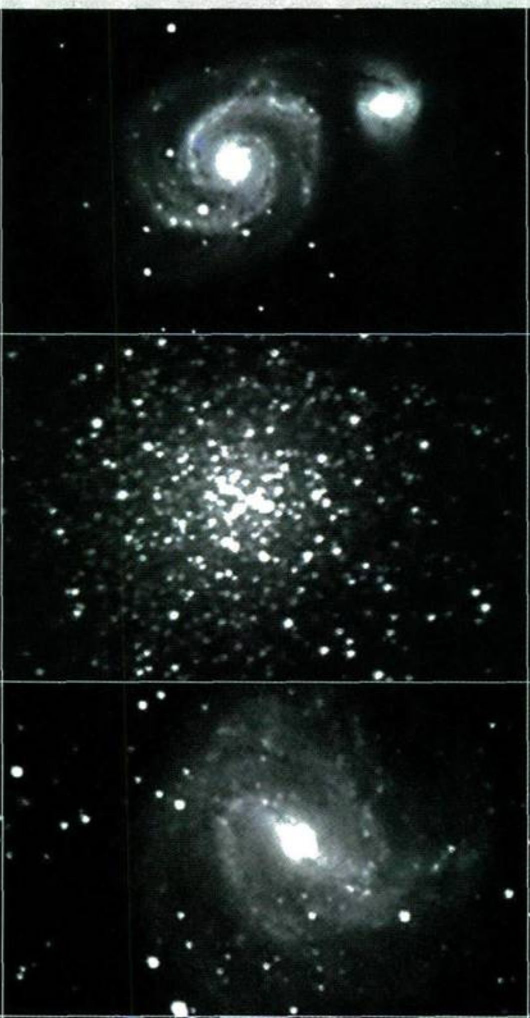
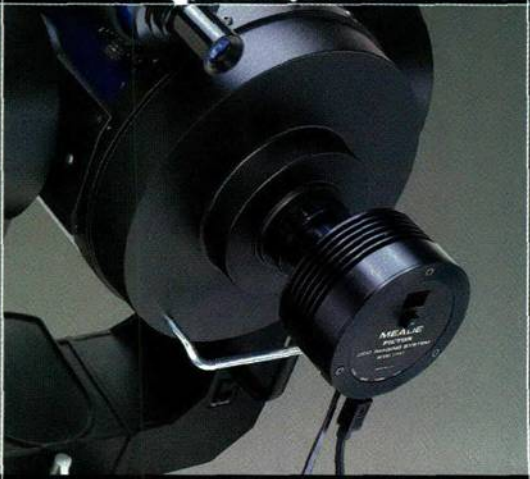
Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.

Pictor 208XT: $495 ***complete***

Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.





Pictor 216XT: $695 ***complete***

Pictor 416XT images: Saturn (in green light), 16" LX200, Dr. Donald Parker; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Crab Nebula (M1), 25" reflector, Jack Newton.

Shipped **FREE** with Pictor 201XT Autoguider, CCD Off-Axis Guider, Image Orienter, and Epoch 2000ip Image Processing Software, as shown!

Pictor 416XT: $1695 ***complete***
includes $800 Meade CCD Equipment System

Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many *observatory* telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 100-page Meade General Catalog.***

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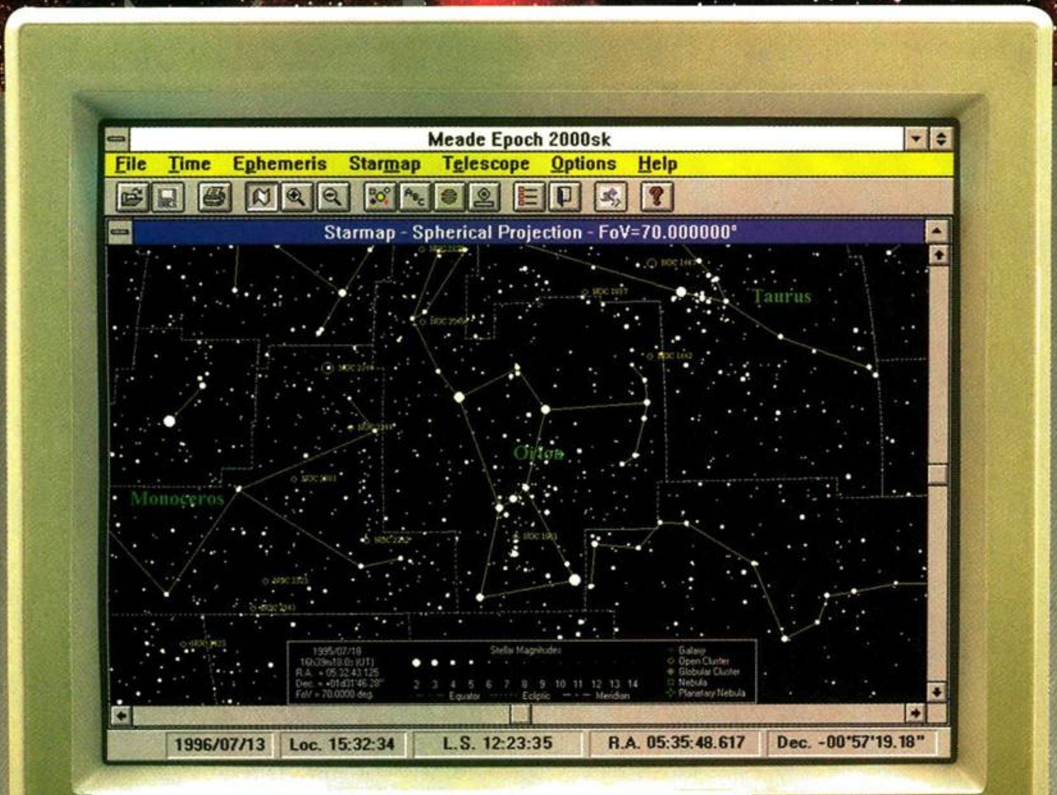
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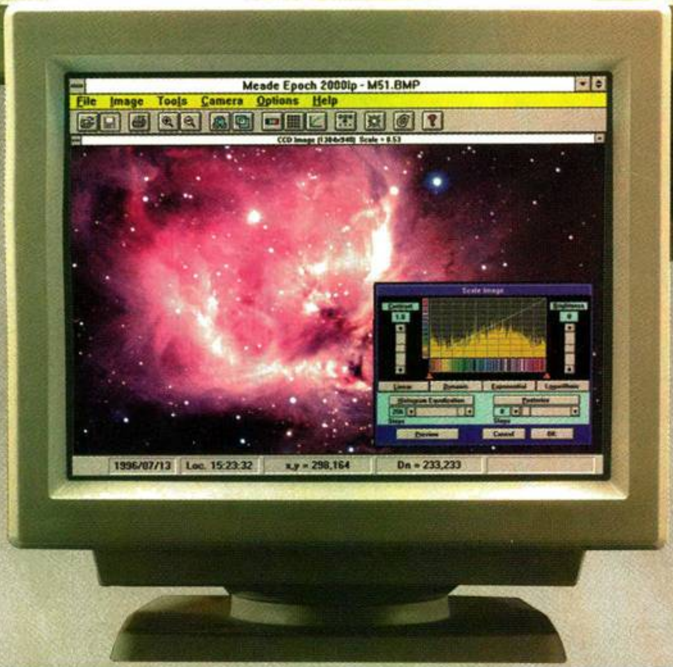
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Now you can use the most advanced, most precise sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** no longer is the Trapezium in Orion, for example, shown as a single point as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

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MEADE STARFINDER DOBSONIANS

***No other competing Dobsonians* include this listing of *standard-equipment* features:**

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right)*, tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package

only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

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1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
3 - **Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

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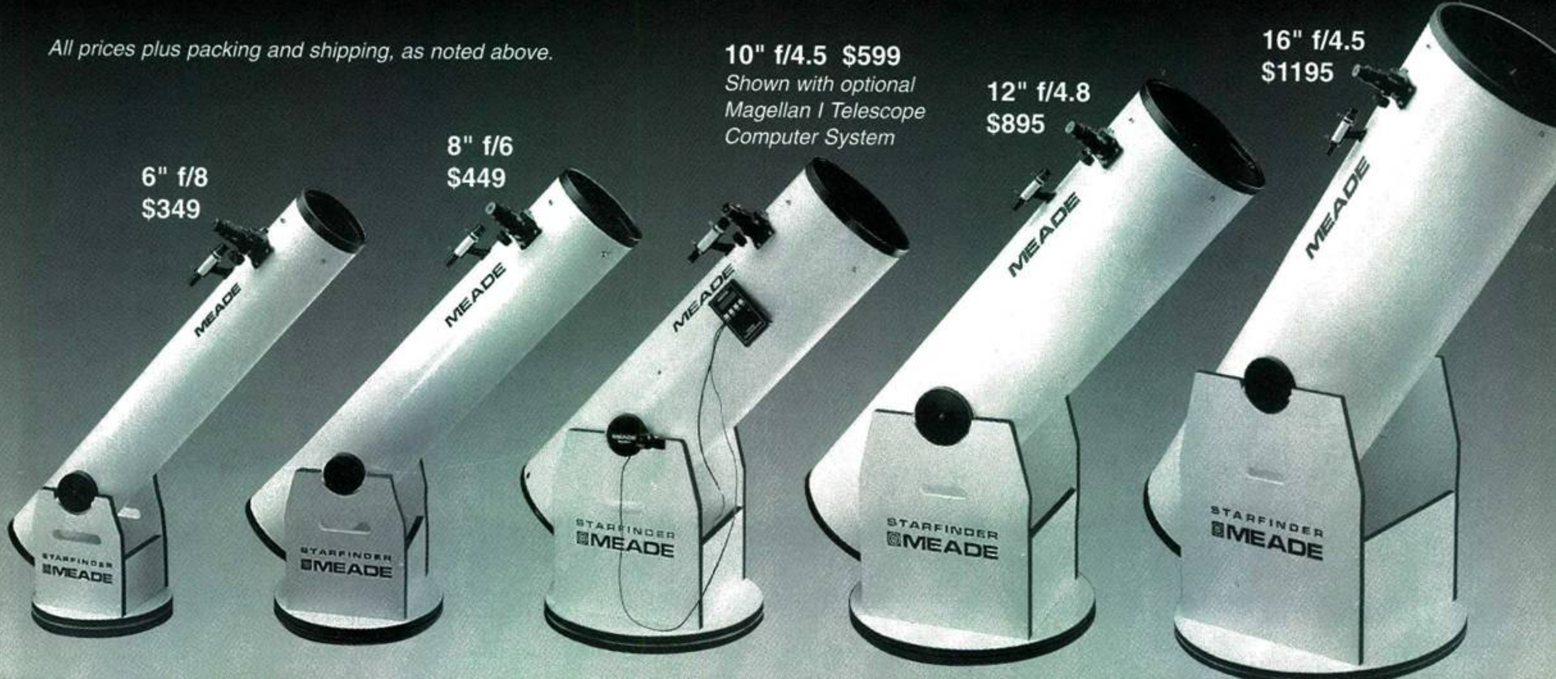
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***

All prices plus packing and shipping, as noted above.



6" f/8
$349

8" f/6
$449

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*

The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 100-page Meade General Catalog.

Write, call, or fax Meade Instruments for your free copy!

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page)*.

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" .... $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" .... 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

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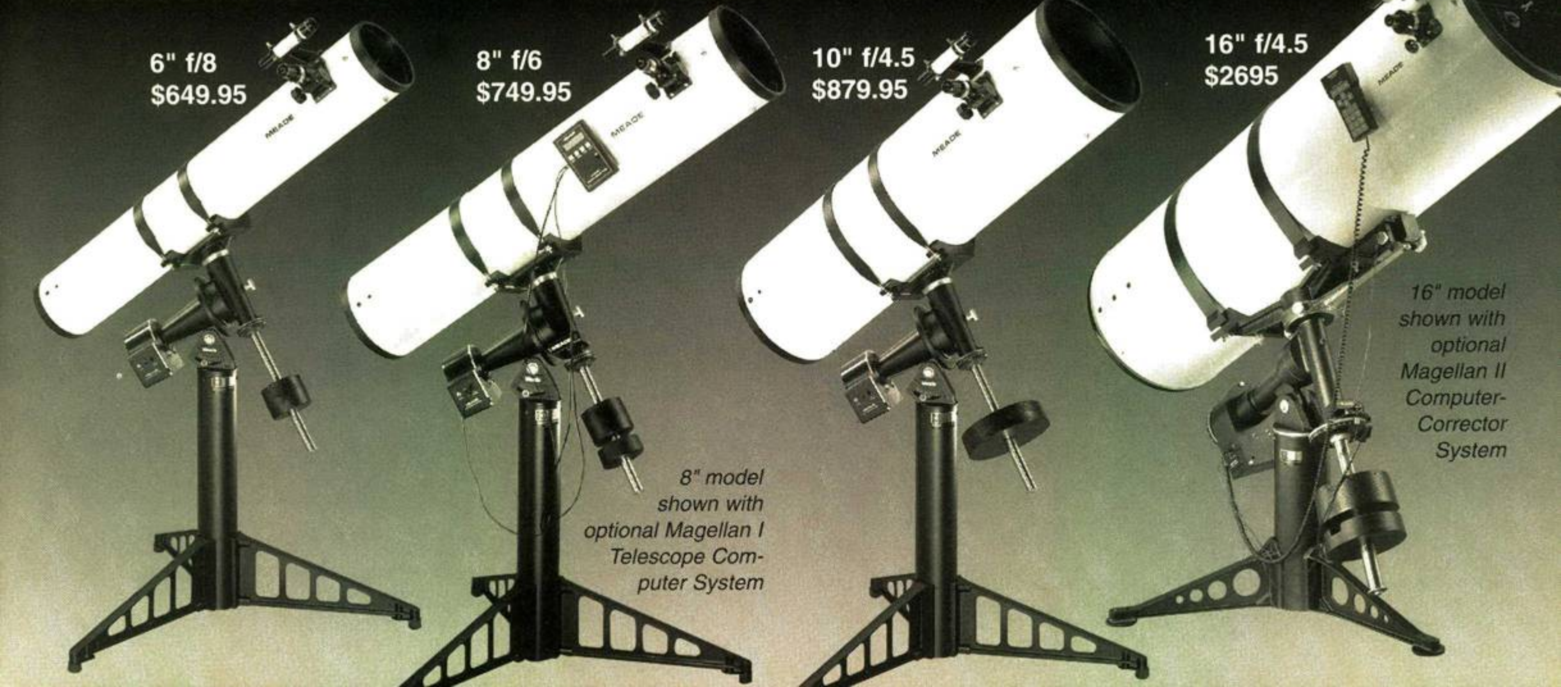
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***

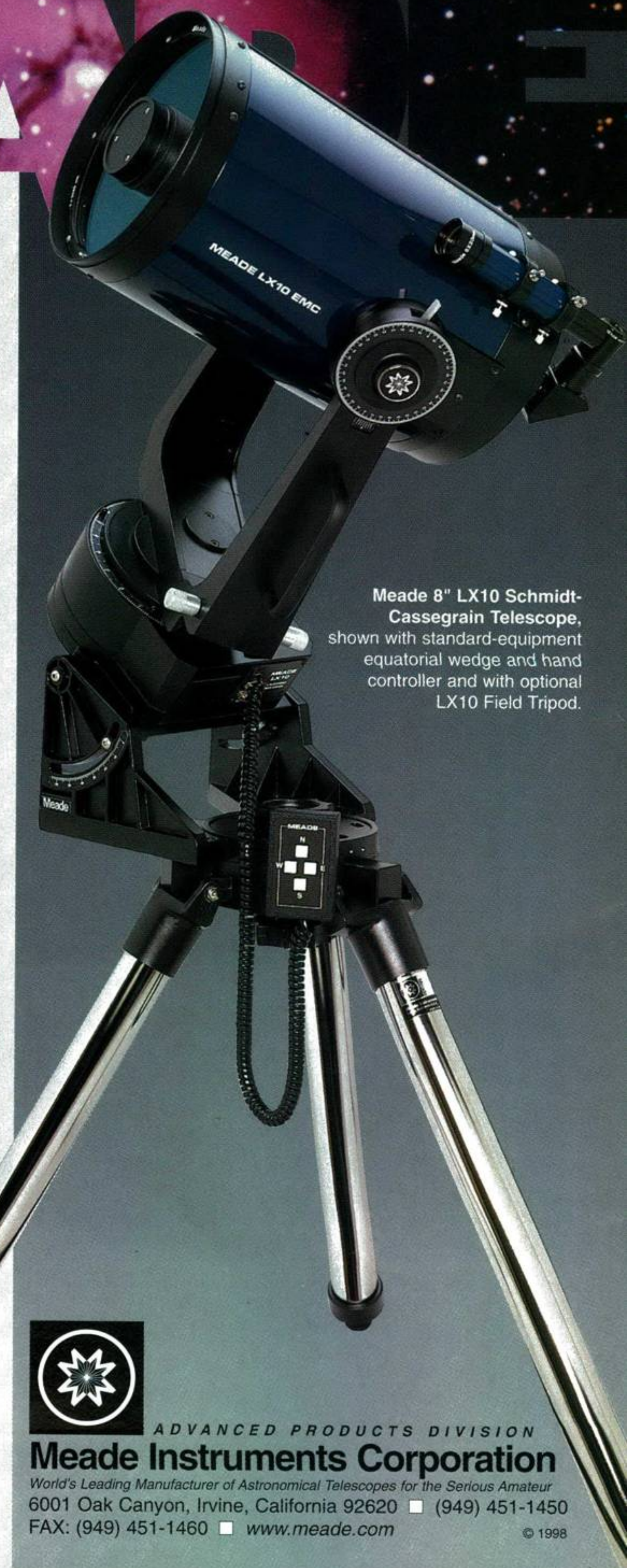


8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

8" LX10

8" LX10 DELUXE



Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) a premium-grade Meade Series 4000 Super Plössl 26mm eyepiece (in place of the standard MA25mm eyepiece); and (c) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed—all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; and with Meade #544 8 x 50mm achromatic viewfinder and Series 4000 Super Plössl 26mm multi-coated eyepiece included in place of the 6 x 30mm viewfinder and MA25mm eyepiece of the LX10. **$1149.** (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	195.
Electric Declination Motor System for LX10	95.
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	375.

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RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™ Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 3000™ Plössls
50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
New!
#910X
#908X

Series 4000 Oxygen-Ⅲ Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-Ⅲ lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

Series 4000 Zoom Eyepiece

The first zoom eyepiece—ever—to yield absolutely uncompromised resolution, color correction, and image brightness. Includes 8 elements, zooms from 7.7mm to 23.1mm with pinpoint imaging from edge to edge. Fully multicoated optics permit 99.8% light transmission at each air-to-glass surface. Apparent field 62° at 7.7mm; fold-down rubber eyecup; threaded for filters; 1.25".

$295. (7.02)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

45° Erecting Prisms .

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

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The Sound of Space

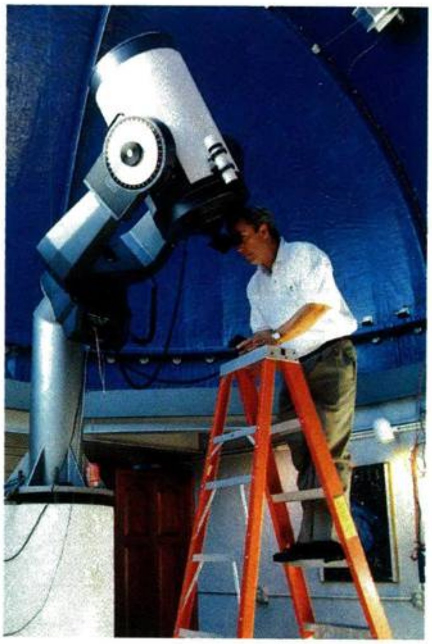
I was glad to read the letter by Gerard DiLeo of Mandeville, Louisiana, regarding the sound of other celestial atmospheres being recorded for the benefit of those who are blind (June 1998). Last year I posed a similar question to the Jet Propulsion Lab in California and received a response that the mission to Saturn with the Huygens probe has been equipped with instrumentation that will enable us to hear the sound of the probe landing on the surface of Titan.

Stephen J. Edberg, a Cassini Discipline Scientist, wrote, "While a microphone might make the virtual experience more complete for us on the ground, it wouldn't teach us that much about the new environment. Consider, for example, whether you would learn more with a microphone on a sand dune as you walk or roll about on it with a magnifying glass, a shovel, a flour sifter, or a miniature chemical lab. Likely not. Titan, however, is such a new and exotic place that scientists planning the Huygens mission have included a microphone on the probe. We will hear it go crunch or splash (it will float, by the way) when it reaches the surface. This is the first microphone to fly on a robotic spacecraft, and we are excited about the possibilities."

This may be the first microphone to fly on a robotic spacecraft, but we now know that the concept of sound for atmospheres other than our own has been taken under consideration. The Huygens probe will give us our first opportunity to hear another celestial body in its natural state of evolution in the universe. The tough part now is having to wait several years for Cassini to reach its destination before we experience it. — *Criss JuDay-Davis, Scottsdale, Arizona*

First Light Celebration

In celebration of Astronomy Day, the St. Petersburg Astronomy Club hosted a public viewing session at their home base, the Science Center of Pinellas County, located in St. Petersburg, Florida. In addition to solar viewing during the day, attendees enjoyed nighttime views of the moon, open and globular clusters, and galaxies in the near-perfect skies.



David Knowlton, St. Petersburg Astronomy Club member, looks through the newly installed 16-inch Meade LX200 in the recently dedicated Carol Samuels Observatory. St. Petersburg Astronomy Club

The highlight of the evening was the first light celebration of the newly installed 16-inch Meade LX200 in the recently dedicated Carol Samuels Observatory located on the Science Center grounds. Club members and science center personnel have worked hand in hand to make the Science Center the premier astronomical teaching and learning center of west central Florida. Additional plans for the observatory include acquiring state-of-the-art CCD equipment and an additional telescope equipped for solar viewing. Plans also include building a raised floor to allow for more comfortable viewing. The astronomy club has a complete optical lab located at the Science Center where members, as well as non-members, can grind their own mirrors up to 16 inches in diameter.

The St. Petersburg Astronomy Club is proud of its association with the Science Center and together we are working to bring the science of astronomy to all who are willing to learn. — *Nancy L. Huff, St. Petersburg Astronomy Club Public Relations Director, St. Petersburg, Florida*

Playing Ping Pong with the Moon

I read with great interest Olen Dillingham's letter on teaching the phases of the moon with ping-pong balls ("Talking Back," April 1998). This approach has been used routinely for at least a decade by CLEA (Comité de Liaison Enseignants et Astronomes), and I can confirm that it is extremely efficient. We use it in a slightly different manner, though: We have the children observe the sunlit ping-pong ball while facing the moon. By comparing the phase of the real moon and the phase displayed by the ping-pong ball, the children can infer that the moon is like a "ball in the sky" and understand why it shows phases.

CLEA is a joint committee of teachers and astronomers. The committee's objectives are to promote the teaching of astronomy and work out new methods of teaching. The committee's activities cover all grade levels, and some of our teaching aids are available in English. Thanks for producing such an excellent magazine. — *J. Vialle, La Rochelle, France*

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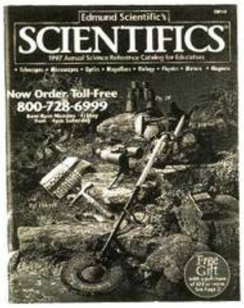

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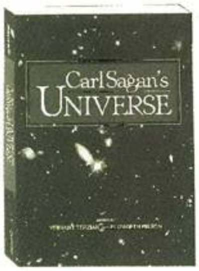
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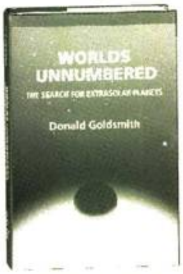
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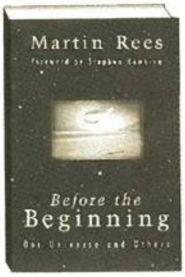
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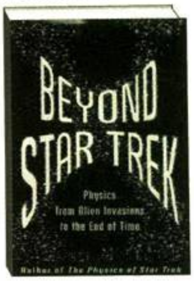
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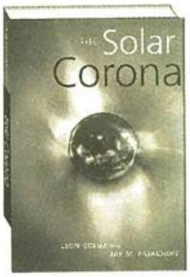
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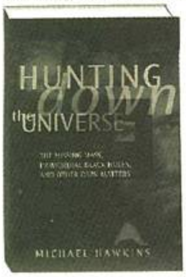
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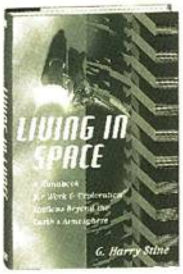
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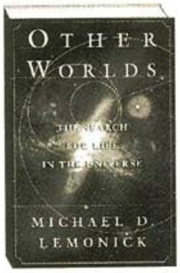
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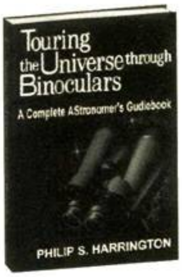
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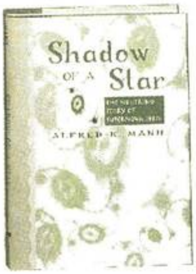
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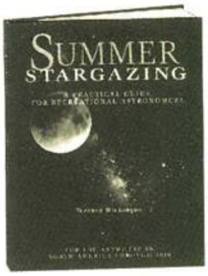
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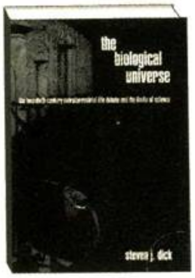
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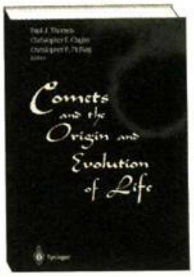
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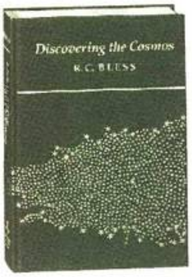
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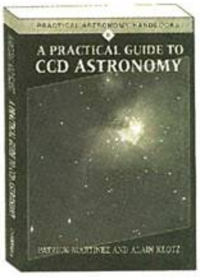
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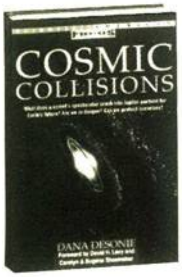
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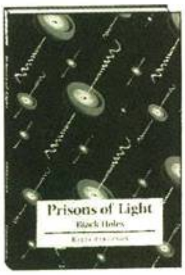
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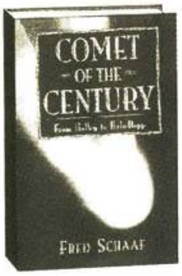
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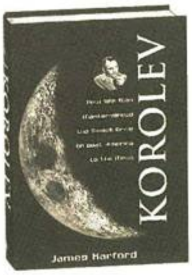
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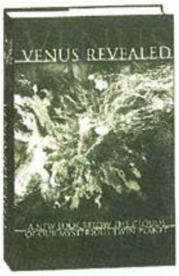
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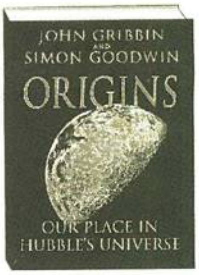
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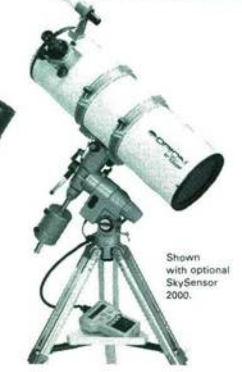

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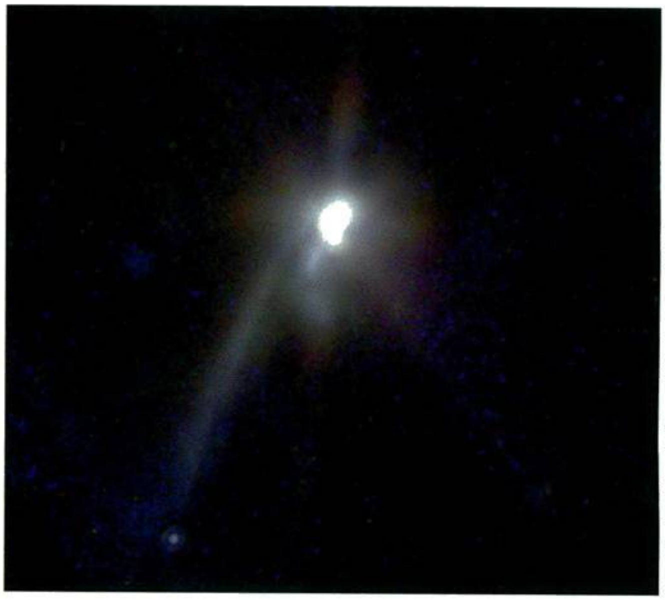

Susan Terebey (Extrasolar Research Corp.), et al., and NASA

The faint blip at the bottom of this Hubble Space Telescope image is possibly the first direct image of an extrasolar planet. The object appears to be connected to a binary star (the bright blob at the top) by a luminous filament about 1,400 AU long. The two stars in the binary are so close together (about 45 AU) that they appear as one star.

▶ Take a close look at the blip at the bottom of the Hubble Space Telescope image to the right. If some astronomers are interpreting it properly, this is humanity's first direct view of a planetary-mass object outside the solar system. All previously known extrasolar planets were discovered indirectly by their subtle gravitational tugs on their parent stars.

Normally, planets are thought of as objects that orbit stars. In this case, however, the object appears to be a runaway protoplanet two or three times the mass of Jupiter that has been gravitationally flung out of its parent star system, never to return. It is destined to roam the frozen depths of interstellar space as it orbits the galactic center for eons.

A team led by Susan Terebey of Extrasolar Research Corporation in Pasadena, California, serendipitously discovered the runaway planet during a survey of young stars in a large star-forming region in Taurus. Terebey's team used Hubble's NICMOS camera to penetrate the thick, dusty veil of this region. NICMOS detects near-infrared light, which can pass through dust just as radio waves can pass through fog to be picked up by your car's tuner.

While examining a NICMOS image, which was taken through three color filters, Terebey noticed a faint light source at the end of a luminous filament approximately 130 billion miles long (1,400 times the Earth-sun distance). "I said to myself, 'This is really weird, what in the world could it be?'" recalls Terebey. "The filament seems to connect the planet to a young binary star, and it's the reason we think they're associated." If the association is real (Terebey calculates that there's only a 1 in 50 chance that this alignment is coincidental), then the object, known as TMR-1C, lies at the same distance as the two stars, about 450 light-years, and has the same age as the binary, between 100,000 and one million years.

Most astronomers are withholding judgment, pending more information about the object. "I was surprised, to put it mildly, that such a bold announcement was made on the basis of the NICMOS picture," says David Golimowski of Johns Hopkins University. "The argument is certainly plausible, but the conclusions are drawn on a whole series of assumptions or unsupported ideas. Still, this is potentially a very exciting result." Adds astronomer J. Davy Kirkpatrick of the California Institute of Technology: "I have a gut feeling it probably won't end up being a planet, but probably something more like a brown dwarf."

Several uncertainties must be addressed before astronomers can determine exactly what TMR-1C is. First, Terebey's interpretation hinges on the object's association with the binary, as indicated by the filament. Yet the filament's origin is a mystery. Terebey suggests that as the planet plows through the dust at about 20,000 miles per hour, it carves out a tunnel where star light can escape the dusty cocoon. Second, an image taken through three filters doesn't provide enough information to determine an object's luminosity or temperature.

If Terebey's team has correctly gauged TMR-1C's distance, luminosity, and the obscuring effects of dust, it is much too faint to be a star. A 300,000-year-old (the age Terebey's team is adopting for TMR-1C) Jupiter-mass planet should still retain significant heat from its formation and should thus glow brightly in infrared light. To estimate its mass, Terebey consulted with University of Arizona astrophysicist Adam Burrows. In Burrows's theoretical model, the inferred infrared luminosity of TMR-1C matches that of a young planet with two or three Jupiter masses. While Burrows's models are considered reliable, his model for very young and low-mass objects such as TMR-1C is unpublished, and as Golimowski says, "It remains completely untested by any data."

To nail down the runaway planet scenario, Terebey's team plans to take spectra of TMR-1C in late September with the 10-meter Keck I Telescope in Hawaii. Spectra will probably yield crucial information about the temperature and chemical composition of the object, which should rule out the possibility that it is a background star darkened by dust that just happens to be aligned with the end of the filament. Terebey adds, "We can take pictures at a later time to follow the track of the object; it should continue to travel in the direction that the filament points out."

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SBIG is proud to introduce the Model ST-5C second generation imaging camera as a high quality affordable CCD Camera for amateur astronomers. The ST-5C utilizes the Texas Instruments TC-255 CCD detector with 10 micron square pixels in a 320 x 240 array. It includes features found only in more expensive cameras such as 16 bit A/D resolution, regulated thermoelectric cooling, internal shutter for automatically taking dark frames, optional internal color filter wheel for automatic tri-color imaging, and the ability to operate as a highly sensitive computer controlled autoguider for astrophotography.

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M109 (NGC 3992) *is a 10th magnitude type FBb barred spiral galaxy located approximately 400 SE of Gamma Ursae Majoris and is approximately 6.40 x 3.50 in size. This ST-5C image is a composit of three 10 minute exposures co-added with CCDOPS and sharpened with CCDSHARP. Taken through a 10" f/4 telescope.* Courtesy Mike Barber/SBIG

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SOHO

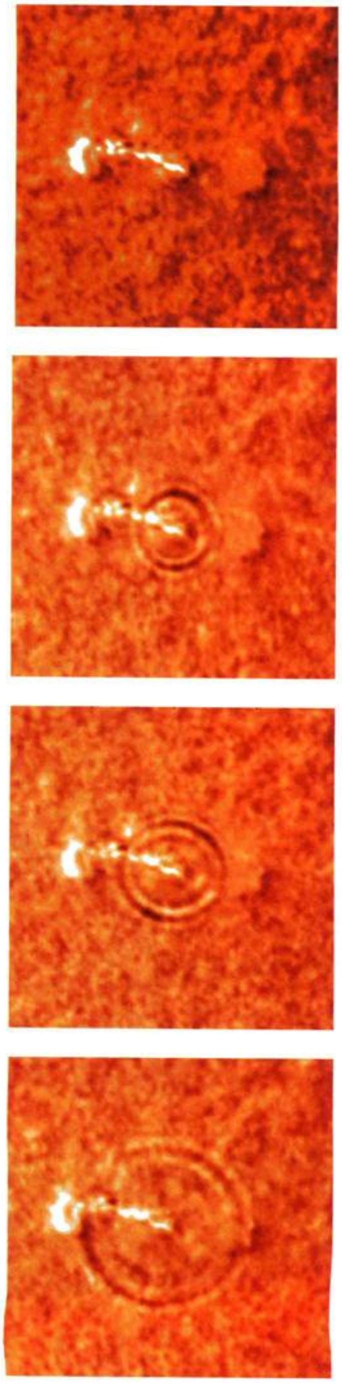
Catching a Solar Wave

▶ Researchers using the Solar and Heliospheric Observatory (SOHO) spacecraft have observed how a solar flare triggers powerful seismic waves that thunder away from the source like ripples on a pond. The July 9, 1996, "sunquake" was similar to an earthquake but 40,000 times more powerful than the one that leveled San Francisco in 1906. "The energy released was equal to completely covering the Earth's continents with a yard of dynamite and detonating it all at once," says Craig DeForest, a Stanford University researcher working with SOHO. The team reported its results at the annual meeting of the American Geophysical Union in Boston.

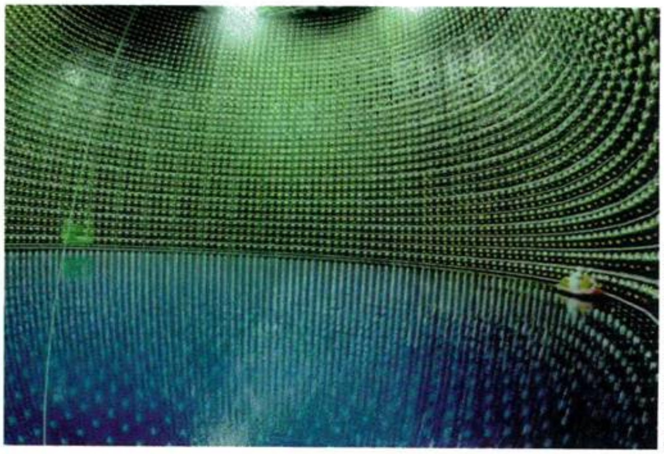
Scientists suspected for years that the sudden, prodigious release of energy in solar flares would trigger seismic waves on the sun. Unfortunately, scientists couldn't accurately forecast the nature and magnitude of seismic waves, which prevented them from observing such events. That changed when Alexander Kosovichev of Stanford University and Valentina Zharkova from Glasgow University in Scotland developed a theory that accurately predicts the seismic phenomenon. A spurt of high-energy electrons created in solar flares is funneled through "magnetic flux tubes" and violently slams into the sun. The collision produces x rays, microwaves, and a shock wave that heat the solar surface.

Using SOHO's Michelson Doppler Imager, Kosovichev and

(see "Solar Waves," p. 26)



An explosive solar flare (top) triggers a seismic wave that spreads out like a ripple on a pond. The solar quake would register 11.3 on the Richter scale, making it 40,000 times more powerful than the 1906 San Francisco quake. The sequence covers 70 minutes. Alexander Kosovichev, Valentina Zharkova, Stanford University, ESA, NASA



Super-Kamiokande collaboration

The 130-foot-high (40 meter) 130-foot-wide Super-Kamiokande neutrino detector in Japan contains the world's purest water.

COSMOLOGY

Neutrinos Have Mass

▶ A team of 120 physicists from four nations has produced strong experimental evidence that neutrinos have mass. While the mass of an individual neutrino appears to be incredibly small, these chargeless subatomic particles exist in such enormous quantities — trillions are passing through your body at near-light speed as you read this sentence — that their combined mass could play an important role in shaping the destiny of the universe.

"This result is not a bombshell, because there are no theoretical reasons why neutrinos should be massless, and previous experiments were pointing in this direction. But it is a relief," says one team member, David Casper from the University of California at Irvine.

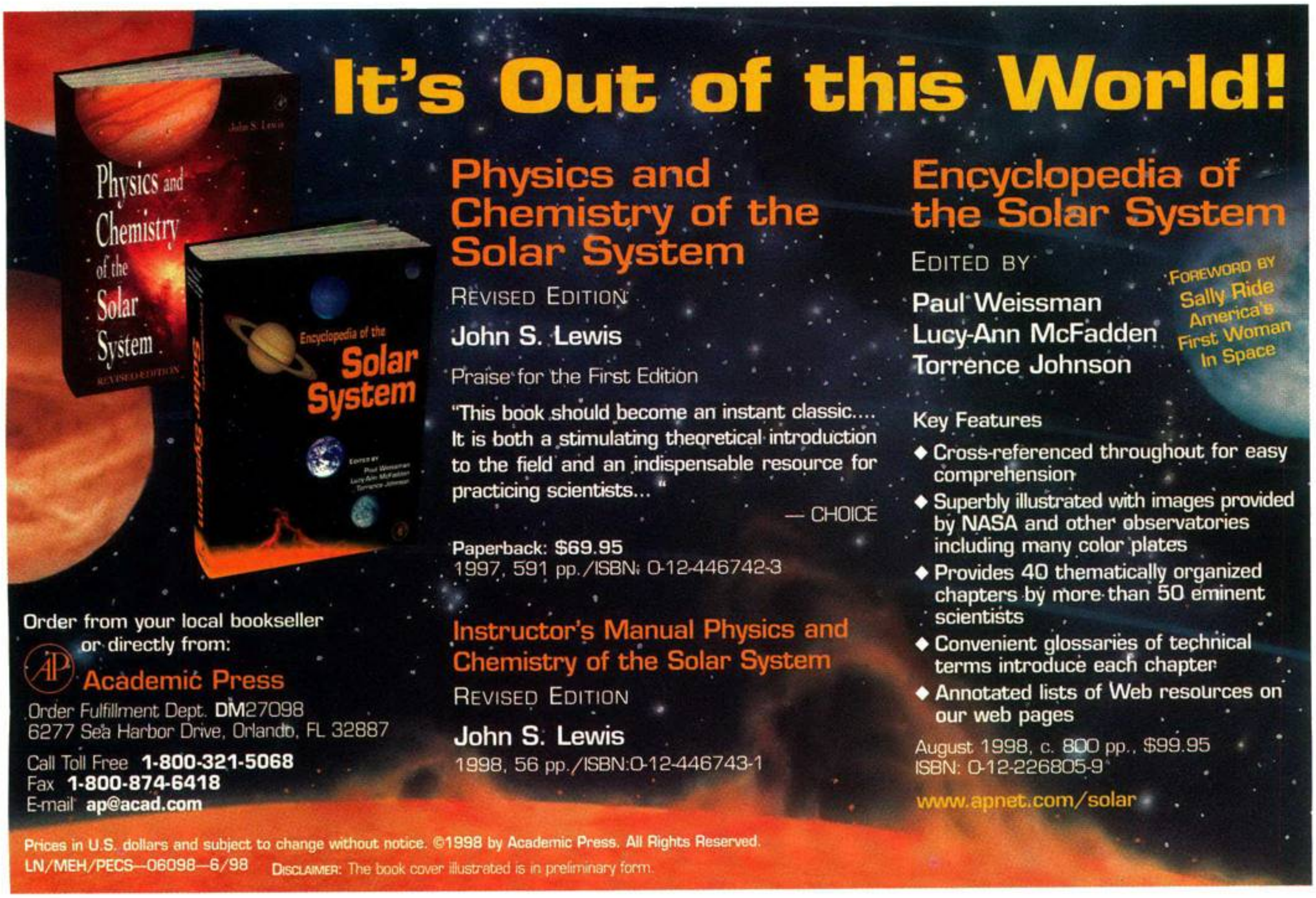
"I think the results are likely to hold up. There is no other explanation for what they have observed," adds astrophysicist John Bahcall of the Institute for Advanced Study, who is not a member of the team.

"It's been an exciting week," says Fermilab cosmologist Rocky Kolb. "First the Spice Girls break up, and now we have the first experimental indication that neutrinos have mass."

The experiments were conducted over the past two years at the Super-Kamiokande neutrino detector, which is buried 2,000 feet (600 meters) under Mt. Ikena in the Japanese Alps. The detector consists of a tank containing 12.5 million gallons (50 million liters) of ultrapure water. The tank is lined with 13,400 detectors that monitor flashes of light resulting from neutrinos interacting with the water molecules.

Neutrinos come in three types (each type also has an antimatter counterpart): tau, muon, and electron. The team observed muon neutrinos changing into tau neutrinos, an "oscillation" that can only occur if these ghostly particles have a nonzero mass. The experiment was incapable of *measuring* the neutrino mass directly, but it could determine the

(see "Neutrinos," p. 26)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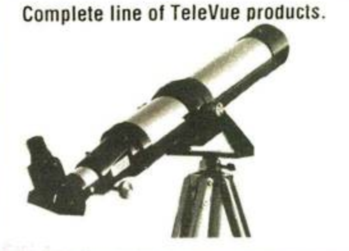

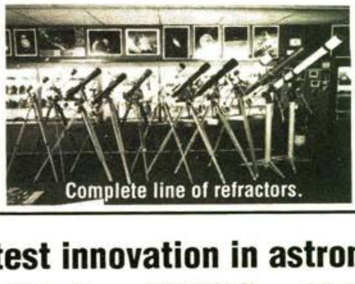

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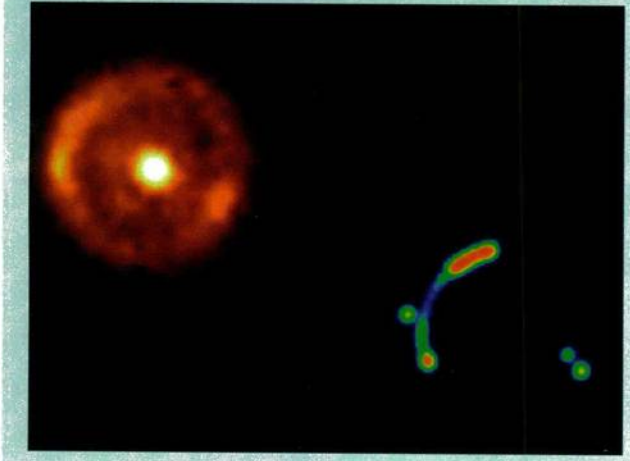
(Solar Waves)

Zharkova found their predicted telltale seismic signature immediately following a medium-sized flare on July 9, 1996. The seismic waves they observed, which were 10 times stronger than they predicted, traveled a distance equal to 10 Earth diameters and attained a velocity of 250,000 miles per hour before fading into the sun's fiery photosphere.

The July 9 flare was the only significant one observed in 1996, a year in which the sun's flare activity was at a minimum. As solar activity reaches a maximum in the next few years, the number of flares will increase sharply. Now that SOHO scientists know how to find the seismic waves, they hope to use them to probe the sun's interior.

GRAVITATIONAL LENSING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A PERFECT CELESTIAL ALIGNMENT between Earth and two distant galaxies produced this cosmic mirage, where the light of the more distant galaxy has been distorted into a ring (left) surrounding the nearer galaxy. Similar gravitational lenses — first predicted by Albert Einstein as an outgrowth of general relativity — have been seen before, but this is the first instance in which both the Einstein ring and the galaxy that creates it have been captured in the same image.

This system, designated B1938+666, was discovered by Peter Wilkinson of the University of Manchester in England and his colleagues using the MERLIN array of six radio telescopes. But the radio emission of the distant galaxy doesn't quite line up with the lens, so the researchers saw only a partial ring (right) with MERLIN. The image of the full ring (left) was taken with NICMOS, the Hubble Space Telescope's near-infrared camera. Luckily, the infrared emission from the distant galaxy aligns perfectly with the lens, creating a complete Einstein ring.

(Neutrinos)

difference in mass between the muon and tau neutrino. From this result, the team estimates that at least one type of neutrino, probably the tau, has a mass of about 0.05 electron volts (10-34 grams) — less than one-billionth the mass of a proton.

Kolb says that unless one of the other two neutrino types is much more massive than the tau, "it doesn't do very much" to explain dark matter — the mysterious form of matter that accounts for most of the mass of the universe but whose nature still remains unknown. Moreover, the combined gravitational pull of all the neutrinos in existence probably is not enough to prevent the universe from expanding forever.

But by showing that neutrinos do in fact oscillate, the experiment goes a long way toward solving a longstanding mystery: why the sun appears to produce only one-third as many neutrinos as predicted by theory. Solar electron neutrinos are probably oscillating into muon and tau neutrinos en route to Earth. Current experiments can't count muon and tau neutrinos coming from the sun. A new neutrino detector in Sudbury, Ontario, however, should soon solve this mystery once and for all.

NEUTRON STARS

Most Powerful Magnetic Field Discovered

▶ When it comes to magnetic fields, it's pretty hard to top neutron stars. These city-sized, collapsed stars typically have fields 10 trillion times stronger than Earth's. But astronomers have identified a new class of neutron stars that apparently has magnetic fields 100 times stronger still, making these the most powerful ever observed in the universe.

A team led by Chryssa Kouveliotou of NASA's Marshall Space Flight Center discovered the new class, called "magnetars," while observing a neutron star known as SGR 1806-20. In 1993 and 1995, Kouveliotou's team observed the neutron star with the Japanese-American ASCA satellite. Since 1996, her team has observed it with NASA's Rossi X-Ray Timing Explorer satellite.

SGR 1806-20 spins about once every 7.5 seconds. But its rotation has been slowing by about three milliseconds per year — a spin down rate 100 times faster than the rate for most neutron stars. Why is it spinning down so fast? Kouveliotou's team has ruled out accretion from a companion star, leading them to conclude that a superpowerful magnetic field must be braking the rotation rate. "The magnetar model is the only one that can account for the observed properties of SGR 1806-20," writes Kouveliotou and colleagues in the May 21 issue of *Nature.*

In 1992, Robert Duncan of the University of Texas and Christopher Thompson of the University of North Carolina predicted the existence of magnetars. Duncan and Thompson also proposed that magnetars give rise to soft gamma repeaters, sources that *repeatedly emit intense* bursts of low-energy ("soft") gamma rays. In their model,

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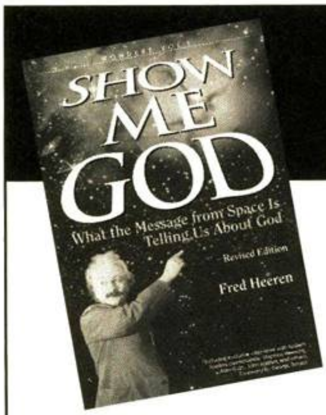

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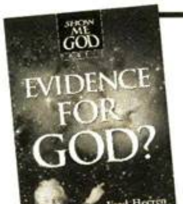

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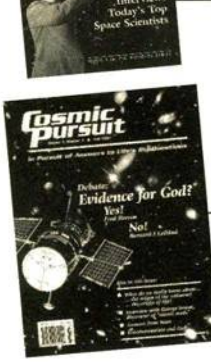

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a magnetar's powerful magnetic field stresses the upper crust, triggering occasional "starquakes." The magnetar's violent shaking drives magnetic waves outward, energizing particles around the neutron star and sparking a flood of soft gamma rays. SGR 1806-20 is one of four known soft gamma repeaters, suggesting that Duncan and Thompson are correct. "We think that soft gamma repeaters are the early stages of the life of magnetars, perhaps the first 10,000 years," says Kouveliotou. "After that, these stars probably don't burst as much."

Because old magnetars rotate relatively slowly, they cool down and don't emit much radiation — making them very difficult to detect. There could be millions in the galaxy. This could explain why many supernova remnants (which result from the same supernova explosions that create neutron stars) don't exhibit neutron stars.

Kouveliotou's team includes Stefan Dieters and Jan van Paradijs of the University of Alabama in Huntsville, Tod Strohmayer of NASA's Goddard Space Flight Center, and seven other astronomers.

TELESCOPES

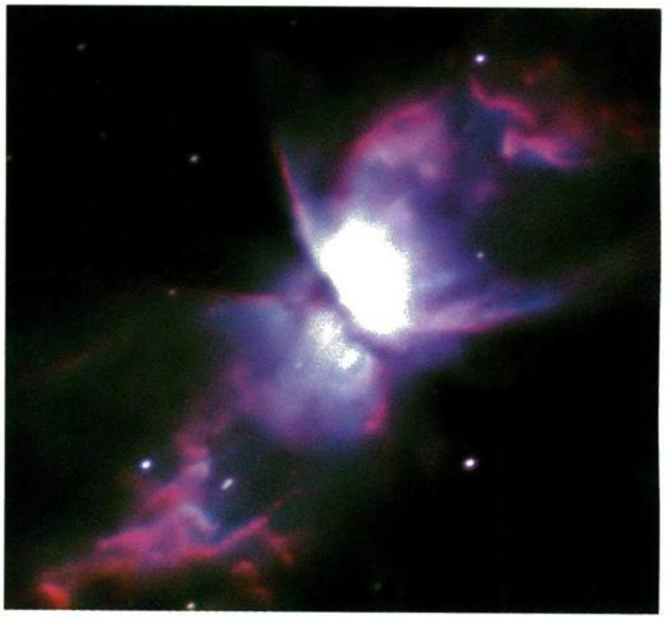
First Light for VLT

▶ American astronomers, beware. Europe is about to take over world leadership in ground-based optical astronomy. On May 27, 1998, the European Southern Observatory (ESO) presented the first astronomical images made with the Very Large Telescope (VLT), still under construction in northern Chile. When completed in 2001, the VLT will be by far the largest optical telescope on Earth.

The VLT consists of four identical telescopes, each with an 8.2-meter mirror. The telescopes are located on Cerro Paranal in the Atacama desert, "the place with the best astronomical climate on Earth," according to Ed van den Heuvel of the University of Amsterdam. Right now, only one telescope is finished; the remaining three are still under construction.

In the second half of May, Unit Telescope 1, as it is called, took its first pictures of star clusters, nebulae, and galaxies. ESO astronomers also tested the tracking accuracy of the giant telescope, and the active control of the thin, meniscus-shaped mirror.

"The performance of the telescope exceeds our expectations," says first-light team member Lex Kaper of ESO. Thanks to its enormous light-collecting area, the telescope was able to register 24th-magnitude stars in two minutes.



One of the VLT's first-light images captured a planetary nebula known as the Butterfly Nebula (NGC 6392). European Southern Observatory

When completed in 2001, the four VLT telescopes can work in unison as an optical interferometer with unprecedented image sharpness. Combined with the huge light-gathering power of the four giant mirrors, this will enable astronomers to study very distant galaxies, extragalactic black holes, and possibly planets orbiting nearby stars.

— GOVERT SCHILLING

Construction of the VLT's four 8.2-meter telescopes will be completed in 2001.

European Southern Observatory

IMPACTS

Comets Showered Eocene Earth

▶ About 35.6 million years ago, primitive tree-dwelling primates had evolved on Earth, and what is now Oregon looked like a tropical Central American rain forest. But a hail of potentially climate-altering comets rudely disturbed the peaceful setting, according to a group of four scientists who investigated late-Eocene sedimentary rock and discovered the chemical signature of a barrage of extraterrestrial impacts.

In the May 22 *Science*, Ken Farley of Caltech, Alessandro Montanari of

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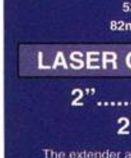

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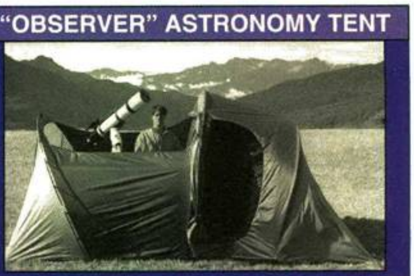

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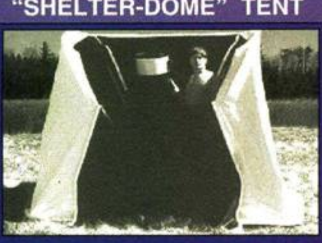

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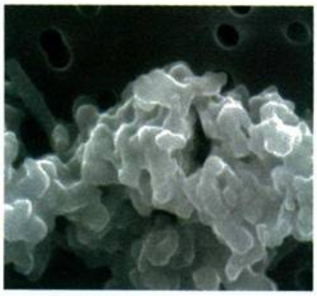

Ken Farley (Caltech)

This 10-micrometer-long interplanetary dust grain was collected recently from Earth's upper atmosphere. The dust is similar to that in the tails of comets that bombarded the sun and planets, including Earth, about 36 million years ago.

Osservatorio Geologico di Coldigioco in Italy, the late planetary scientist Eugene Shoemaker, and Lowell Observatory astronomer Carolyn Shoemaker wrote that "an isolated impulsive event" in the late-Eocene epoch, possibly the gravitational jolt from a passing star, may have perturbed the Oort comet cloud far beyond Pluto and unleashed a comet shower upon the inner solar system, including Earth.

Geologists have known for years that the 62-mile (100 km) Popigai crater in northern Siberia and the 56-mile (90 km) Chesapeake Bay crater were formed about 35 million years ago. In earlier work, a group led by Montanari found two layers, or "spikes," of impact debris in late-Eocene sedimentary rock. Both of these closely spaced layers contained iridium, a platinum-like element that is a thousandfold more abundant in extraterrestrial objects than it is in Earth's crust.

Farley's team has found elevated levels of helium-3 in late-Eocene sediment. A millionfold more abundant in extraterrestrial than terrestrial material, helium-3 is considered a tracer of fine-grained interplanetary dust. Helium-3–rich sediments accumulated on Earth's ocean bottoms 500,000 years before the first large late-Eocene impact and continued for 2.5 million years.

After considering several possible explanations for the pattern of craters and iridium and helium-3 deposition, the researchers wrote that a single event most likely perturbed the Oort cloud and sent a swarm of comets looping toward the inner solar system. The researchers also concluded that the perturbation must have produced a large number of Earth-crossing comets, and they further speculated that it took about 2.5 million years for all the comets in the solar system to be ejected.

MARS GLOBAL SURVEYOR

Getting into Hot Water on Ancient Mars

▶ At the May meeting of the American Geophysical Union, Mars Global Surveyor (MGS) scientists announced further evidence that liquid water existed in Mars's past.

The first set of evidence came from the spacecraft's Thermal Emission Spectrometer (TES) team. TES determines the composition of material from the spectrum of infrared light emitted from the surface. The team discovered a 200-mile-wide (300 km) area near the martian equator with an unusually strong concentration of hematite, a form of iron oxide. Hematite has been previously found on Mars and

Golf 31, SETI 0

Big Ear, a football-field-sized radio telescope in Delaware, Ohio, has been demolished so real estate developers can build a golf course. The telescope was constructed by Ohio State University physicist John Kraus and his students between 1956 and 1963. During the late 1960s, Big Ear conducted the first deep survey of the radio sky, cataloging thousands of galaxies and quasars. For the past 25 years, Big Ear has been devoted to the search for extraterrestrial intelligence (SETI). In 1977, it picked up what some astronomers consider to be the most compelling evidence for extraterrestrial civilizations: a powerful, narrow-band radio signal from deep space known as the "WOW!" signal. The golf course will be the 31st in Delaware County, Ohio.

Egyptian for Stonehenge?

An assembly of huge stones in Egypt's Sahara Desert was recently confirmed by University of Colorado astronomer J. McKim Malville to be the oldest known astronomical alignment of megaliths in the world. Known as Nabta, the site is believed to be more than 6,000 years old (predating Stonehenge and other prehistoric sites by about 1,000 years) and consists of a stone circle, a series of flat, tomblike stone structures, and five lines of standing and toppled megaliths. The circle, 12 feet in diameter, contains four sets of upright slabs, two sets aligned in a north-south direction and the other two providing a line of sight toward the summer solstice horizon. The significance of this orientation is as yet unknown.

J. McKim Malville (Univ. of Colorado)

A stony oasis? Nabta, a group of carefully placed mammoth stones in Egypt, predates Stonehenge.

Cold Equals Old

A new candidate for coldest star in the universe is out to prove the old age of our galaxy. An international team led by University of Wyoming astronomer David Ciardi has discovered a tepid star no hotter than 1700 kelvins (2600° F), making it at least 7400° F cooler than the sun. This unnamed Milky Way star, about 160 light-years from Earth, once burned brightly. But the old-timer's greedy binary partner, a dense white dwarf star only about the Earth-moon distance away, has long been gobbling it up. So much of the star's material has been consumed that it is now only 1/25 the mass of the sun. The astronomers calculate that this heat-devouring process had to have begun at least 10 billion years ago, making the Milky Way at least that old.

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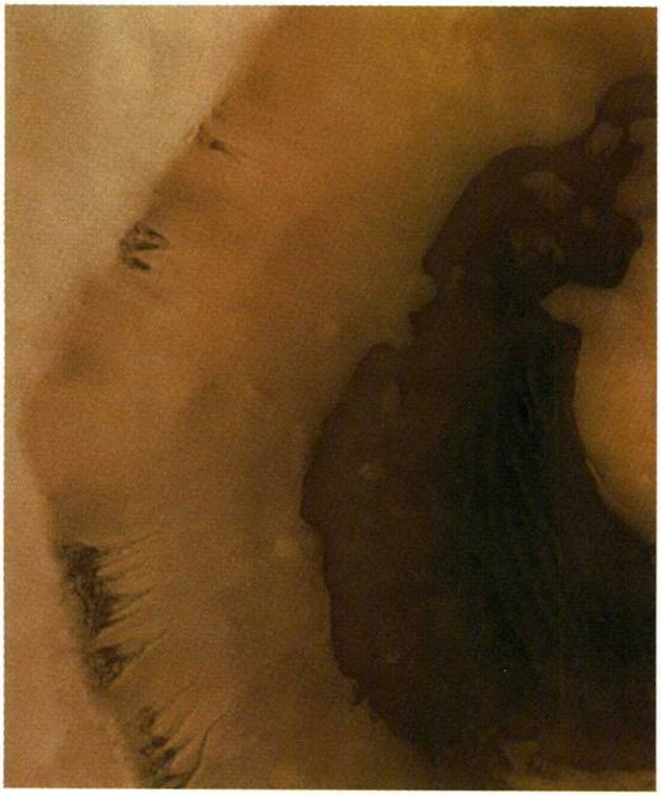


Malin Space Science Systems/NASA

The channels in the crater walls and the dark floor deposits suggest that liquid water once ponded in this crater, which is located at 65° south latitude.

is thought to contribute to the planet's red color.

The strong concentration measured by TES is typical of the growth of hematite crystals in hot water containing large amounts of dissolved iron. The hematite might have originated when iron dissolved in hot water from geothermal activity and was left behind when the water evaporated. The hematite crystals could also have formed in large bodies of standing water. Either way, the deposit provides new evidence that abundant liquid water existed at some time during the history of Mars. "The existence and location of these deposits provide important information to aid in the selection of future landing sites for exploration and collection of samples for return to Earth," says TES principal investigator Phil Christensen of Arizona State University. "This is one of the best places to look for evidence of life on Mars."

WEBSITE

Check out *Astronomy*'s website for news as it happens — http://www.astronomy.com

In another development, a newly released MGS photo shows unusual deposits on a crater floor that indicate the crater may have been flooded at one time. Channels eroded into the crater walls suggest seepage of water from underground aquifers through the crater wall and onto the floor of the crater. Also, a dark deposit on the crater floor suggests that sediments settled onto the floor when it was flooded. Scientists cautioned, however, that the dark deposits can be interpreted in other ways.

After a month-long hiatus when the sun was between Earth and Mars, Mars Global Surveyor is again taking data, and the spacecraft appears to be in excellent health. Full-scale mapping from the 250-mile-high circular orbit will commence in March 1999.

— **William K. Hartmann, Planetary Science Institute**

GALILEO

A Pinch of Salt on Europa

▶ Salt may not just be of the Earth, as the old saying suggests. Observations from the Galileo spacecraft's Near Infrared Mapping Spectrometer (NIMS) indicate that Jupiter's icy moon Europa may also contain salt mineral deposits. Not only will some clichés need revision, but so too will ideas about life in the universe.

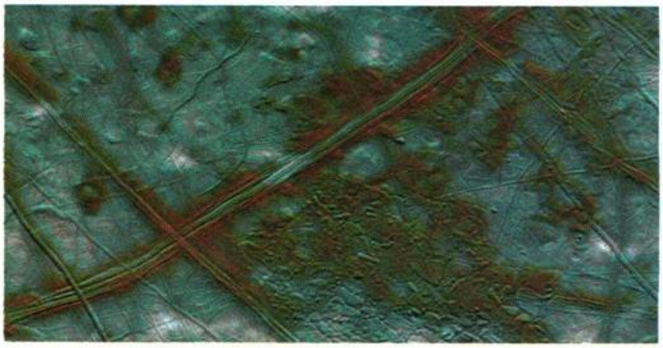
By looking at NIMS data, Thomas McCord of the University of Hawaii's Institute of Geophysics and Planetology and his colleagues found evidence of salt deposits near cracks on Europa's frozen surface. Their results support the idea that the icy shell conceals a briny sea beneath and, quite possibly, a life-sustaining environment. "The existence of salt minerals on the surface suggests an ocean exists, and liquid water is a basic requirement for sustaining life. If the ocean is briny as well," says McCord, "that means it also has the nutrients that support life."

NIMS measures the sunlight reflecting from Europa in many different wavelengths. The reflections, called spectral signatures, provide clues to the materials on the surface because different materials reflect light in unique ways. Just as a detective can match fingerprints to a suspect, scientists can match a spectral signature to its source.

When McCord and his colleagues looked at the signatures from Europa, they recognized some of the sources as salt. And they didn't just find ordinary salt, they found salt that has a crystal structure containing water molecules. "It's what one would expect to find if a liquid ocean were dissolving minerals out of the basic materials that condensed to form Europa," says McCord.

To find out if Europa has an ocean — a likely prerequisite for life — NASA plans to launch a Europa orbiter mission in 2003. A

Europa's icy surface — seen here in a high-resolution Galileo image — contains salt deposits.



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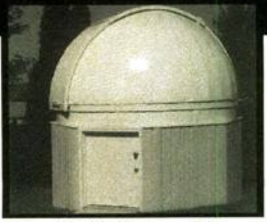

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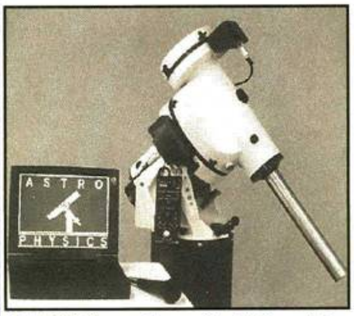

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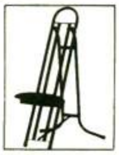

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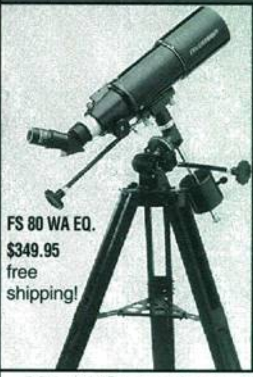

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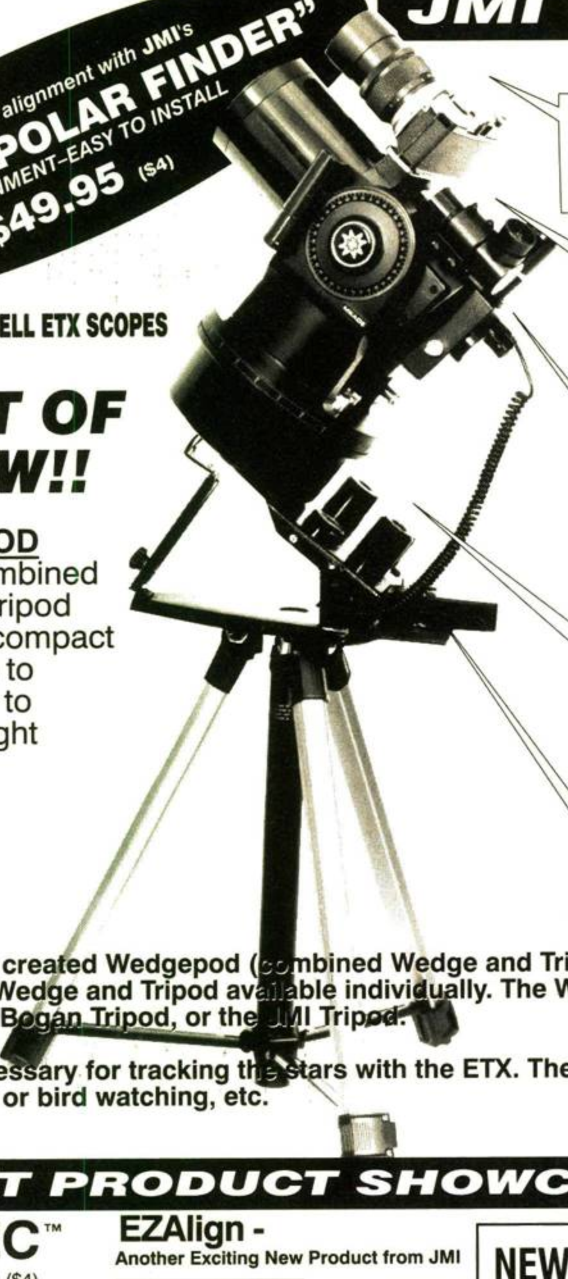

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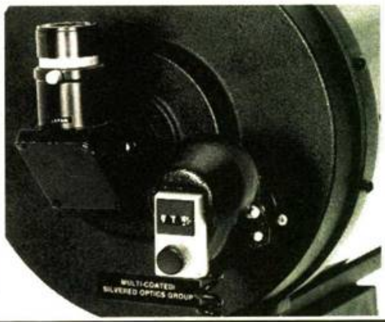

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- *Founded in 1979, the Texas Star Party has grown to be the largest star party held under superbly dark skies — in the Davis Mountains of western Texas, near McDonald Observatory. Each spring some 800 enthusiasts bring their large telescopes and explore deep space from the TSP.*

- *More than 800 observers each summer attend Starfest, held for the past 17 years by the North York Astronomical Association near Mount Forest, Ontario. Canada's largest observing session gets underway under very dark summer skies; the event also hosts talks and exhibits.*

Astrofest

Astronomy: David J. Eicher

- *Held at Camp Shaw-Waw-Nas-See near Kankakee, Illinois, Astrofest attracts about 800 observers each year to point their telescopes skyward, listen to a variety of speakers, and share their love of the sky under the guidance of the Chicago Astronomical Society.*

- *The Winter Star Party draws more than 1,000 observers each winter to the Florida Keys, where they receive dark-sky views of the winter Milky Way and swap favorite observing stories. This star party is an ideal destination for family groups. The star struck can stick to their telescopes on Marathon Key, while spouses and children can swim, snorkel, dive, fish, and see the colorful sights of Key West.*

- *For 10 years the Tucson-based International Dark-Sky Association has held an annual meeting to discuss light pollution: a growing problem as cities expand in all directions.*

- *For the past 108 years, the Astronomical Society of the Pacific has held an annual meeting, which in recent years includes an amateur meeting called Universe, that shifts from place to place. The 1998 meeting in Albuquerque, New Mexico, featured many talks from professional and amateur astronomers, observing sessions, workshops, and telescope exhibits. The 1999 meeting will be held in Toronto in July.*

- *The fifth annual Enchanted Skies Star Party takes place this October in the shadow of the Very Large Array, the world's greatest radio astronomy facility, near Socorro, New Mexico. About 200 people are expected to share views under some of the darkest skies in the continental United States.*

- *York County, Pennsylvania, hosts the Mason-Dixon Star Party, held each summer since 1990. Telescope judging, afternoon talks, a swap table, and vendors round out this growing event, which drew 150 people this year.*

Stellafane

Astronomy: David J. Eicher

- *Black skies are the primary attraction at the Oregon Star Party, held each summer at Indian Trail Springs in the Ochoco National Forest, some 190 miles east of Portland. At a 5,000-foot altitude, the hardiest deep-sky observers have much to savor.*

Winter Star Party

Astronomy: Robert Burnham

BACK

GREAT STAR PARTIES

Astronomy: Alan Dyer

Riverside

- *Grandfather of amateur astronomy gatherings, Stellafane hosts more than 1,500 amateur astronomers each summer on the summit of Breezy Hill near Springfield, Vermont. The pilgrimage began in August 1920 when a small group decided to grind their own telescope mirrors — their instructor was Russell Porter, who went on to help design the 200-inch Hale telescope on Palomar Mountain — and the event still focuses on telescope making.*

- *Begun in 1983, the Okie-Tex Star Party, which attracts 750 wide-eyed observers, has been held alternatively in Oklahoma or on the Prude Ranch in West Texas, site of the Texas Star Party. The late autumn event allows owners of large telescopes the opportunity to see the winter Milky Way from an exceptionally dark-sky site.*

- *The Table Mountain Star Party takes place each summer at a remote, dark-sky site near Ellensburg, Washington. Last year more than 1,500 people came to the event to see deep-space objects in their full glory, hear a distinguished set of speakers, and have fun with such competitions as Astronomy Jeopardy.*

- *The most intense showcase of telescopes and technology for backyard astronomers may be found at the Riverside Telescope Makers Conference, held annually near Big Bear City, California. The 30th RTMC in 1998 drew nearly 2,000 who marveled over the exhibits, vendors, and legendary swap tables. Despite the focus on equipment, observing takes place too.*

- *More than 200 observers trekked to the Nebraska Star Party last year, an event begun in 1993. The Prairie Astronomy Club puts on this event each summer at the Merritt Reservoir near Valentine, Nebraska.*

- *Under the dark of night at Camp Reeves, near Robbins, North Carolina, some 200 observers enjoy crystal-clear skies at the Mid-Atlantic Star Party. Held in autumn each year, the event offers not only nighttime observing but also solar viewing, talks by amateur astronomers, and awards for telescopes and viewing challenges.*

Astronomy: Alan Dyer

Mt. Kobau

- *The Ponchartrain Astronomical Society puts on the Deep South Regional Stargaze each year at Percy Quin State Park near McComb, Mississippi. For the past 17 years the event has drawn about 200 amateur astronomers to the darkness of the southern wilderness and the wonders of the late autumn skies.*

- *Each year members of the Miami Valley Astronomical Society present the Apollo Rendezvous and Telescope Fair. The 28th Apollo Rendzevous took place at the Dayton Museum of Natural History in Dayton, Ohio, in June. Talks and exhibits gave way to dark-sky observing at John Bryan State Park each night.*

- *The 51st meeting of the Astronomical League, a federation of American astronomical societies, took place in French Lick, Indiana, in July. Each year ALCON moves to a new city and offers an extensive array of activities including talks, observing, workshops, a telescope show, and an astrophotography competition.*

- *The Mt. Kobau Star Party takes place each summer in a remote area of the Okanagan Valley, British Columbia. The 15th star party took place this summer and featured a week of dark-sky observing at an altitude of one mile, plus assorted talks.*

Deconstructing the MOON

If astronomers are right, the moon was formed in a catastrophic impact some 4.5 billion years ago.

by Ray Jayawardhana

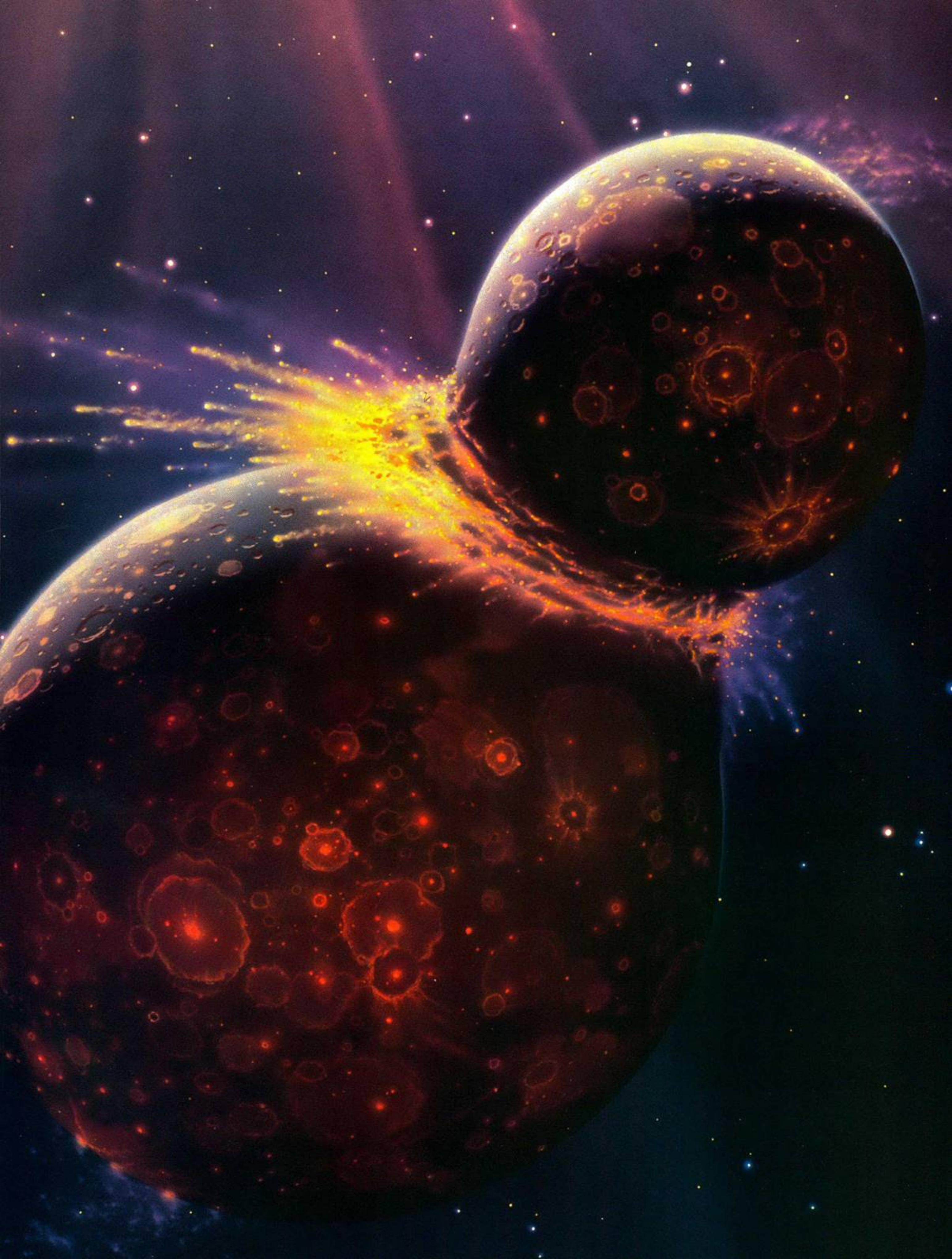
IMAGINE YOU HAVE STEPPED INTO A TIME MACHINE and gone back in time 4.5 billion years to see the solar system just 50 million years after the sun formed. Chunks of rock that haven't been swept up into planets are still chaotically flying about. You see that one of the largest chunks, about the size and mass of Mars, is on a collision course with the still-forming Earth. Suddenly, this rogue planet slams into Earth at some 25,000 miles per hour, violently launching a huge plume of material into space. In the throes of the collision, Earth's primordial atmosphere boils off into space, and its mantle melts into an ocean of magma. Within hours, the material blown into space forms a beautiful ring around young Earth, and debris in the ring starts clumping together. From a catastrophic event — the most violent impact Earth has ever suffered — the moon is born.

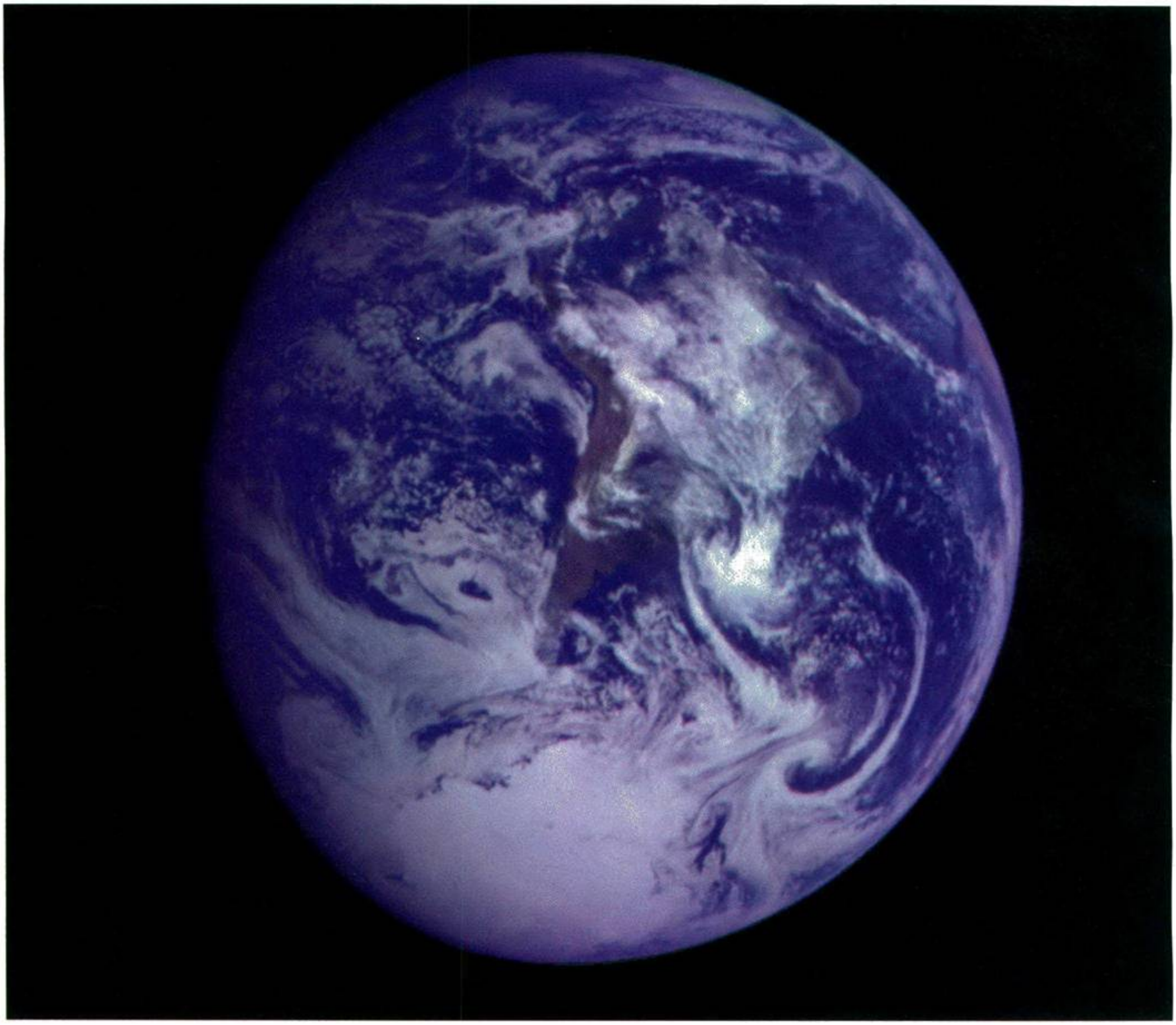
This is the emerging consensus among scientists attempting to unravel the genesis of Earth's cosmic companion. Although recent research in a variety of fields has bolstered and refined this picture, scientists still lack a complete understanding of how the moon formed. "The past several years of work have told us that it's not as simple as we thought 10 years ago. For instance, maybe more than one giant impact is needed," says Robin Canup of the Southwest Research Institute in Boulder, Colorado, who models the moon's formation on computers.

Scientists have mulled over different ways of making the moon for more than a century. George Darwin, son of the famous naturalist Charles Darwin, was among the first to put forth a model for the moon's origin. In 1878, he suggested that a newly-born, still-molten Earth started spinning faster and faster until it threw off a piece of itself as big as the moon, sort of like a merry-go-round spinning out of control and sending a rider flying. But Darwin's model fails a critical test; it can't explain the total spin rate — a quantity physicists call "angular momentum" — of the Earth-moon system. As Harvard University planetary scientist Alastair Cameron points out, if Darwin's model were true, "Both the Earth and moon would have to be spinning four times faster than they actually are."

A second theory suggested that the moon assembled itself independent of Earth from primitive rocks and dust, just as other planets in the solar system did. "If that happened, both would have about the same percentage of metallic iron in their bodies," Cameron explains. But the model didn't hold up. Data from seismic instruments left behind by astronauts suggest that the moon's core has an iron deficit.

Before Earth was fully formed, a large body smashed into it at a grazing angle, leading to the moon's origin. Joe Tucciarone





Due to geological activity and wind and water erosion, Mother Earth shows no trace of the catastrophic impact that gave birth to the moon 4.5 billion years ago. Galileo took this portrait of our home planet during its December 1990 flyby. NASA/JPL

A third possibility is that the moon formed elsewhere in the solar system and was later captured by Earth's gravity. Cameron's calculations show this scenario to be virtually impossible; it's much more likely that the moon would have either hit Earth directly or received a gravity kick that set it flying off into deep space. What's more, according to Cameron, the capture scenario "still leaves you with the iron problem. A body as big as the moon that formed from the same material as other planets would have an iron core like Venus, Earth, and Mars."

By the early 1970s, it was clear that all three of the most popular existing theories for the moon's origin had serious flaws. Thus, along with William Ward, a former Harvard University colleague who now works alongside Canup at the Southwest Research Institute in Boulder, Cameron came up with a new idea that could explain both the moon's composition and the total spin rate of the Earth-moon system. They reckoned that the moon formed from the debris of a giant impact between Earth and a roaming planet roughly the size of Mars.

At about the same time, William K. Hartmann and Donald Davis of the Planetary Science Institute in Tucson, Arizona, had come to the same conclusion from an entirely different direction. Following up on the ideas of Russian scientist Victor Safronov, they estimated that there had been bodies near the newly formed Earth large enough to blast out enough mantle to make the moon. The two groups learned about each other's work at a planetary science conference in 1974.

For a decade, both groups' models received scant attention, because, as Hartmann explains, "Other researchers had been taught to abhor catastrophes as a mode of explanation in geophysics. They felt that the giant impactor had literally been conjured up out of the blue." Finally, at a 1984 conference on the origin of the moon, the "giant impact model" — more popularly known as the "Big Whack" — took center stage. By then, most researchers had come to believe that collisions among hundreds of planetesimals — some as big as the moon — were required to build up the planets to their present sizes. In addition, it was clear that none of the other theories for the moon's origin could account for its composition and the total spin of the Earth-moon system.

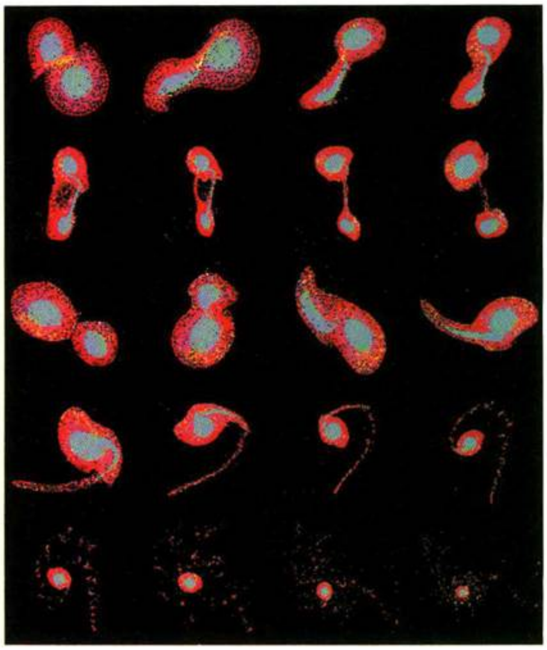
Over the years, Cameron and his collaborators, as well as a team led by Jay Melosh of the University of Arizona in Tucson, have performed dozens of computer simulations of the impact and its aftermath. Their simulations require an impactor about the size of Mars with roughly a tenth of Earth's mass to leave the Earth-moon system with the right amount of spin. In each simulation, the impactor is destroyed, and a plume of rock, magma, and vapor is boosted into Earth orbit. Occasionally, a fairly large rocky moon is formed. The impactor's iron core falls onto the deformed proto-Earth and sinks to its center. That explains why the moon has very little iron; after all, the debris that went into it came from the rocky mantle material of the impactor and Earth. The model can also account for the lack of water and other volatile compounds on the moon. Because the giant impact heated the ejecta to high temperatures, the volatiles would have escaped into space as gases.

Computer simulations of the giant impact that Cameron and others have been doing usually end once a hot disk of material has just formed around Earth, only hours after the impact occurred. So, how does all that stuff come together to make the moon? That's the question Robin Canup set out to answer. In two papers, one with Larry Esposito of the University of Colorado, and the second published in the September 25, 1997, *Nature* with Shigeru Ida of the Tokyo Institute of Technology and Glen Stewart of the University of Colorado, Canup presented the first simulations of how that debris disk coalesced into the moon.

Canup and her colleagues started their simulations where Cameron's simulations ended, once the debris has cooled down and formed swarms of individual particles of varying sizes, a process that could take up to 100 years after the impact. In 27 different models, the researchers varied the number and the sizes of the particles, and followed them up to see what happened. In every case, the particles invariably clumped together to form one or two moons in less than a year at a distance of about 14,000 miles (22,500 km) from Earth. The particles in the outer disk clumped together pretty easily, but those in the inner regions could not form big clumps because Earth's gravity pulled them apart much like Saturn's gravity pulls apart ring particles when they collide. "Once the particles in the outer disk accreted to form the moon, its gravitational forces likely scattered the inner disk material back on to Earth," explains Canup. "That means an initial disk mass of two to five lunar masses is required to yield the moon."

That, in turn, implies a larger impactor than previously suggested — one with about three times the mass of Mars. "The problem with this requirement is that such an impact also produces an Earth-moon system with two to two and a half times the angular momentum of the current Earth-moon system," Canup points out. "The laws of physics tell us that the angular momentum

The moon appears tranquil today, but its origin was anything but. Galileo took this image of the moon's Western Hemisphere in December 1990, showing parts of the near side and far side. The 600-mile-wide Orientale Basin is the bull's-eye in the middle. NASA/JPL



A computer simulation models how a giant impact sideswiped Earth, blasting enough material into orbit to form the moon. Alastair Cameron (Harvard University) of the Earth-moon system has been very nearly conserved over the past 4.5 billion years."

In one third of the simulations, two moons form instead of one. "That would have been quite a sight," notes Canup. But two moons would grace Earth's sky for only a brief time. In every one of the trials, either the inner moon crashes back to Earth or the two moons collide in only 1,000 to 10,000 years.

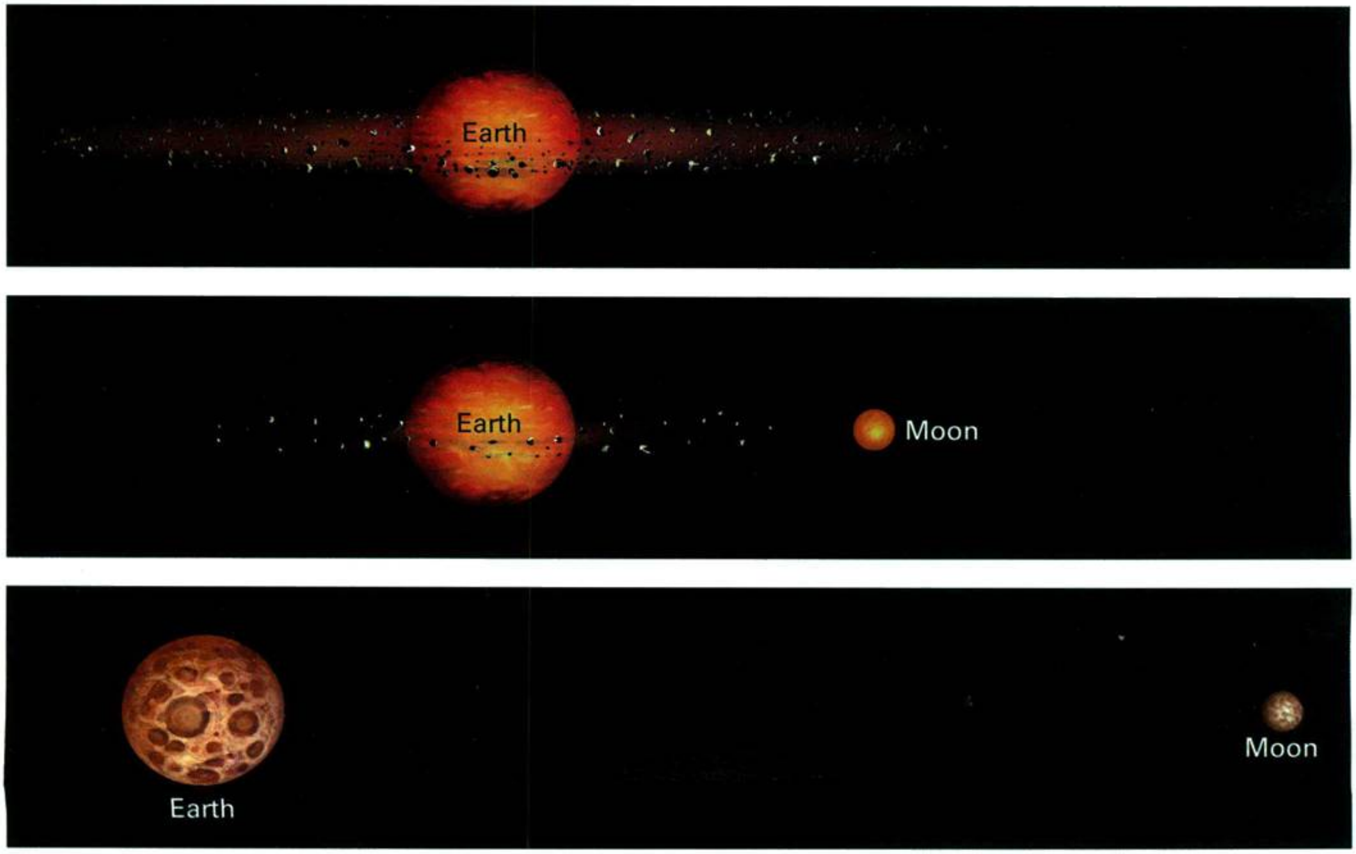
At the time of its birth, the moon was much closer to Earth than it is today. Canup's simulations suggest it formed about 14,000 miles from Earth, whereas it is now orbiting at an average distance of 239,000 miles (380,000 km). Gravitational interactions between Earth and the moon give rise to tidal forces that push the moon outward. These tidal forces were much stronger when the two bodies were closer together, so the moon receded at a faster rate. Within a few hundred million years of its birth, the moon had already moved out to half its present distance. It is still receding, as confirmed by radar reflectors left by astronauts, but at a slower-than-snail's pace of about 1.5 inches (4 cm) per year.

While these simulations can form a moon of the right size and composition, the nagging angular momentum problem remains. One way around this problem is to invoke a second large impactor, about the size of Mars, smashing into Earth millions of years after the first one. Big Whack II could have altered Earth's rotation rate enough to reset the angular momentum of the Earth-moon system. While this scenario could potentially explain all the characteristics of the Earth-moon system, both Cameron and Canup consider it too *ad hoc* for their tastes.

To get around the angular momentum problem, Cameron and Canup went back to the drawing board. In Cameron's most recent simulations, which he presented this past March at a planetary science conference in Houston, Texas, the impactor delivers a glancing blow. After sideswiping Earth, part of the impactor survives. It slows down and swings halfway around Earth and hits a second time. This double whammy, it seems, is necessary to blast enough material into Earth orbit to form the moon. The collision ejects a long tail of material into Earth orbit, with a sizeable blob at the tail's far end (the blob is an intact piece of the impactor that's thrown into Earth orbit). "That blob is the principal seed for growing the moon," Cameron explains.

Cameron's new results suggest that the impact occurred fairly early in Earth's history, before our

Immediately after the giant impact, a disk of debris forms around Earth (top). In just one year, the material blasted into orbit accretes to form the moon at a distance of about 14,000 miles from Earth (center); most of the remaining debris falls back to Earth. After the moon forms, tidal interactions with Earth cause the moon to slowly spiral away (bottom). By 100,000 years after the impact, the moon is about 40,000 miles from Earth. *Astronomy*: Elisabeth Rowan



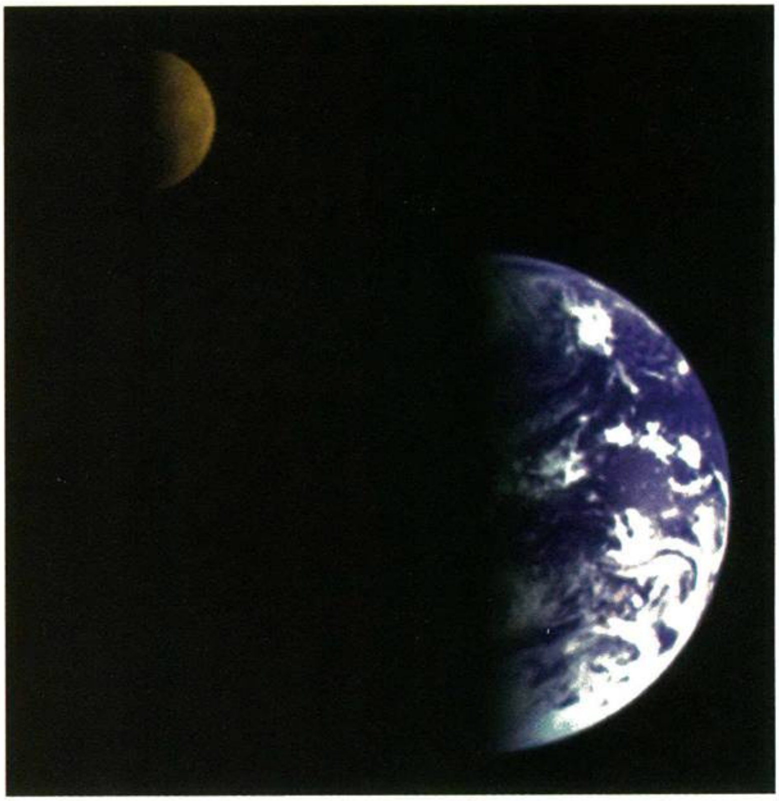
planet was fully assembled. If Earth were more than about half its current mass at the time of the collision, an impactor that could yield our moon would have left the Earth-moon system with too much angular momentum. An impactor with twice the mass of Mars and a proto-Earth with half its present mass are the ingredients Cameron's recipe needs to provide enough mass for forming the moon while still leaving the Earth-moon pair with the right amount of angular momentum.

This scenario does raise one concern, however: If Earth were much smaller back then, how did it grow to its present mass? The simple answer is that Earth accreted much of its mass after the moon formed. But then the moon would have accreted quite a bit of mass as well and should have more iron than it actually does. "That's an issue we need to address in greater detail," Cameron concedes.

When was the moon born? To make an estimate of the moon's birthdate, University of Michigan geochemist Alex Halliday and colleagues studied the amounts of two elements — hafnium and tungsten — in 21 lunar samples brought back by Apollo astronauts. Hafnium radioactively decays into tungsten with a half-life of nine million years. By measuring the ratio of the two elements in moon rocks and comparing that to their ratio in primitive meteorites, the researchers could estimate the time that elapsed between the formation of the solar system and the birth of the moon. In a paper published in *Science* last November, Halliday and coworkers reported that the moon was assembled a mere 50 million years after the solar system itself was born 4.6 billion years ago. Previous estimates had placed this event 40 million years earlier.

Canup and Craig Agnor of the University of Colorado have conducted several simulations of planetary growth that have shown that large impacts tended to occur about 50 to 90 million years after the solar system formed. "All the pieces are fitting together. The timing from the computer simulations seems to agree fairly well with the geochemical evidence," says Canup.

A giant impact also implies a melted early Earth. The energy released when a Mars-sized body collided with Earth must have been enormous. The resulting heat was more than enough to blow away Earth's primordial atmosphere into space. In addition, Earth's mantle must have been heated to several thousand degrees Celsius, melting it into a so-called magma ocean. But, as Michael Drake of the University of Arizona's Lunar and Planetary Laboratory points out, "Earth doesn't show any credible evidence of ever being melted." If there once was a magma ocean, as it cooled, different minerals would have frozen out first and either risen to the top or sunk to the bottom. That should have altered the composition of the mantle. Geochemists like Drake have found no signs of such alterations. However, Drake is quick to add that "absence of evidence is not evidence of absence."



Cosmic companions whose origins are inextricably linked together: Galileo snapped this image of Earth and the moon en route to Jupiter. The moon's brightness has been artificially enhanced. NASA/JPL

According to Halliday, "It's not clear that any evidence of the impact would have been preserved in Earth's mantle . . . All that memory might have been erased by four billion years of geologic activity." Cameron agrees: "Earth is a very dynamic body, and it may have wiped out any traces of the impact." Still, Earth's geochemistry remains a potential stumbling block for the giant impact origin of the moon.

Although the computer simulations still can't completely explain all the characteristics of the Earth-moon system, the giant impact model is now the runaway favorite scenario for the birth of the moon. After all, it can account nicely for the moon's makeup and the spin of the Earth-moon system — two of the most important criteria that any model must meet. As Drake puts it, "Not all the details have yet been worked out, but the giant impact model explains the main features of both the Earth and moon." And that means, according to Cameron, "giant impact is pretty much the only game in town right now" for those who worry about the moon's origin.

Contributing editor Ray Jayawardhana, a graduate student at Harvard University, studies star formation. He was the leader of a team that recently imaged a possible planet-forming disk around the young star HR 4796A. His previous feature article for Astronomy, *"NASA's Next Space Observatories," appeared in the January 1998 issue.*

PUZZLING OUT PARALLAX

Figuring the distance to stars and galaxies challenged both ancient Greeks and modern cosmologists.

by James Trefil

THE UNIVERSE MAY BE THREE DIMENSIONAL, BUT our view of it is not. The sky looks to us like a two-dimensional bowl, offering no clue as to the actual distance to any of the lights we see. A bright distant star looks the same as a dim close one. Consequently, if we want to ask one of the most fundamental questions we can — "How big is the universe?" — we have to find some way of adding a third dimension to what we see in the sky. This has been a continuing problem from the time when human beings first raised their eyes to the sky until today, when our "eye" is more likely to be something like the Hubble Space Telescope.

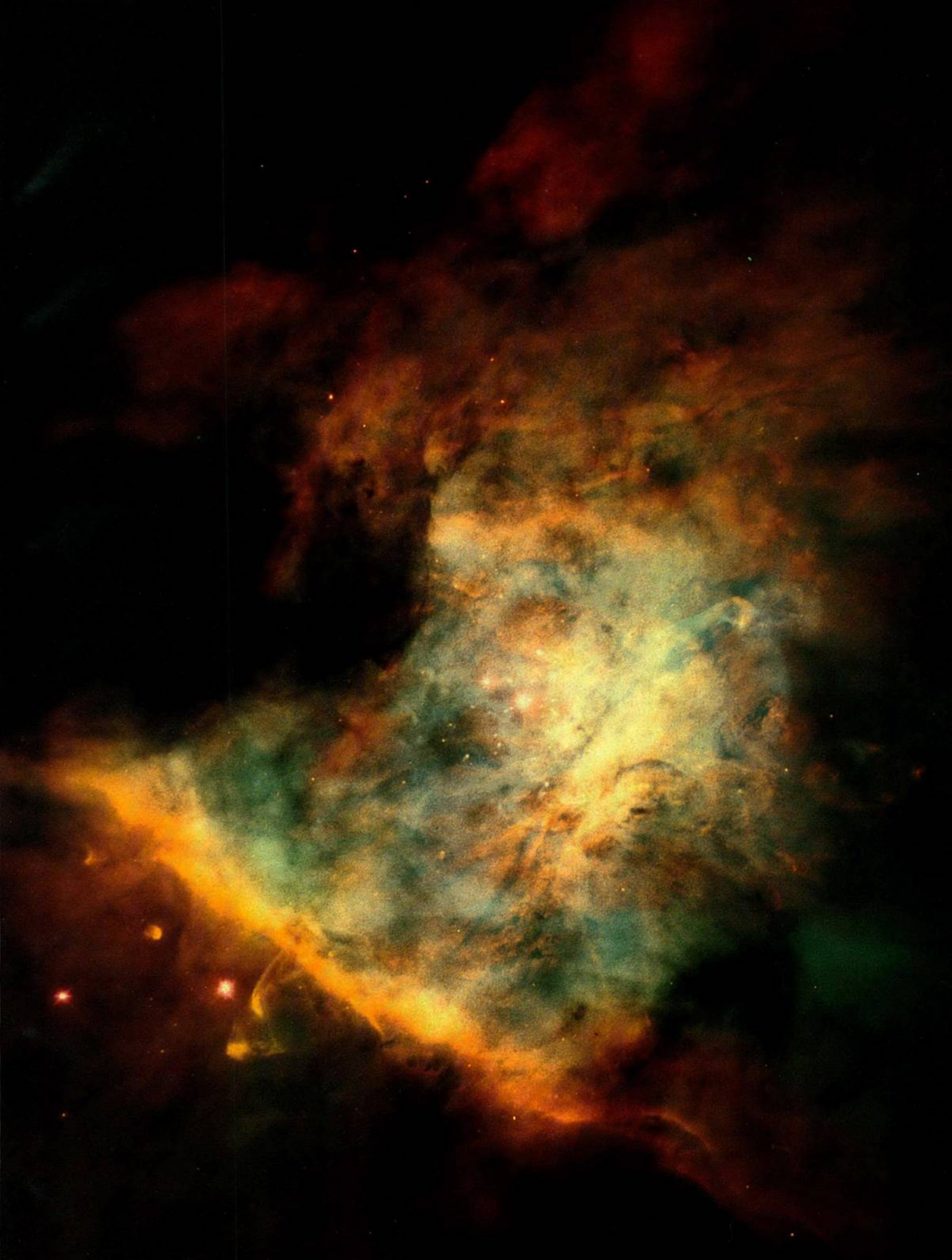
Determining the size of the universe has gone through several stages. First, it involved determining the distances to objects in the solar system — a problem that wasn't solved until the late 1600s. Then it involved finding the distances to the stars — essentially, to finding the size of the Milky Way. It was the first of these measurements, carried out in 1838, that I nominate as a "Great Moment." And finally, there is the continuing problem of finding the distances to the farthest visible galaxies, a problem that must be resolved if we want to know the age of the universe itself. And as with all great intellectual quests, this one starts with some fairly simple ideas.

Hold your finger out at arm's length and look at it with one eye closed. Now open that eye and close the other one. Do you notice how your finger seems to move against the background? This phenomenon, as everyday and simple as it seems, gives us the tool for measuring distances — not only the distance between your eye and your finger, but the distance between Earth and the stars. It is called parallax.

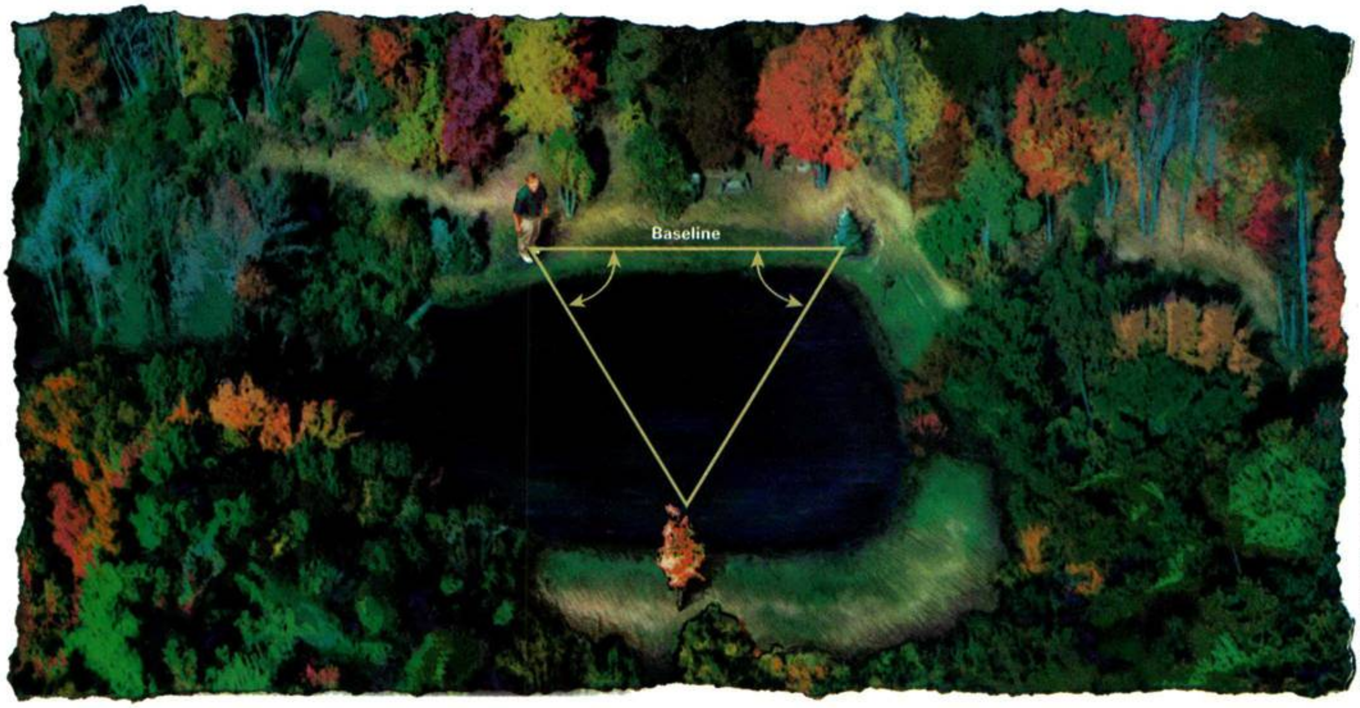
Here is how it works: Suppose you want to measure the distance to an object, but can't do it directly. You may want to know how far it is across a lake but not have a boat at your disposal to make the trip. You could pick a landmark on the opposite shore — a tall tree would do — and then make a couple of measurements (see drawing, page 48.) You begin by measuring a line on your side of the shore. You might get a tape measure and lay out a 50-foot line. This length would become the "baseline" of your measurement. At one end of the baseline you measure the angle between the tape and the line of sight to the tree, then repeat this measurement at the other end. These measurements define a triangle whose vertices are the tree and the two ends of your tape. Now you know the length of one side of a triangle and the size of two of its angles. From this information you can determine everything else about the triangle, including the lengths of the other two sides. These other sides, of course, represent the distance to the tree.

Any instrument you use to measure the angles is going to have some limit — some smallest angle beyond which it cannot go. You are familiar with this fact from ordinary measuring devices. If you have a ruler, for example, there will be a smallest

Astronomers use triangulation to estimate the distance to nearby stars. From those estimates they infer distance for faraway regions like the Orion Nebula, at right, which is about 1,500 light-years from Earth. HST



division of the scale. If it's an eighth of an inch, it's obvious that the ruler can't distinguish between lengths that differ by 1/64 of an inch. In the same way, there will be some smallest angle that can be measured by any instrument, some angle below which the instrument is incapable of discerning differences.



To calculate the distance from the man to the tree below, you must create a baseline, imagine lines of sight to the tree from both ends of the baseline, and measure the angles between the baseline and the lines of sight. From this you can figure the dimensions of the triangle, including the distance from man to tree.

All illustrations by *Astronomy*: Elisabeth Rowan

In the case of finding the distance to a tree using a 50-foot baseline, as in our example, the smallest angle we can measure determines the maximum measurable distance to the tree. If our instruments measure to an angle of one degree and the tree is more than about 2,500 feet (about half a mile) away, we won't be able to tell the difference between the angles of the lines of sight measured at the two ends. As far as we are concerned, the lines of sight are parallel and the object is an infinite distance away.

To get around this difficulty, we can do one of two things: use more accurate instruments, so that we can tell the difference between the two angles, or increase the baseline, so that the difference in those angles becomes larger than the limit of accuracy of the instruments. In the case of the tree, using instruments capable of measuring to half a degree would allow us to find the distance to trees more than 5,000 feet (about a mile) away from us, or, if we can't change the instruments, we could get the same effect by increasing the baseline to 100 feet. The history of our ability to measure distances in the sky can be thought of as a kind of leap-frogging of competencies in increasing the accuracy of our instruments and increasing the baseline of our measurements.

The first baseline available to astronomers was the radius of Earth itself. They realized that they could observe the same object from two different points on Earth and then use the (presumably known) distance between those two points and the phenomenon of parallax to determine the distance to that object. This was first done successfully by the Greek astronomer Hipparchus, who compared measurements of an eclipse of the sun on March 14, 190 B.C., from the Hellespont (the present location of Istanbul) and the town of Alexandria in northern Egypt. By measuring the angles to the moon from these two observing points, Hipparchus was able to determine that the distance from Earth to the moon at the time of the eclipse was about 71 times Earth's radius. For reference, the modern accepted distance to the moon is 59 Earth radii. To convert his result to an actual distance, Hipparchus would have had to multiply his result by the radius of Earth.

This brings us to the question of how well the ancients knew that number. The radius of Earth was first measured by Eratosthenes of Cyrene (276–195 B.C.). His technique was to measure the shadow cast by a pole of known height in Alexandria at the summer solstice at the same time that the sun cast no shadow in a deep well in his hometown of Cyrene, which is located just about on the tropic of Cancer. From these two measurements he concluded that the distance between the two towns was 1/50 of the circumference of Earth (see diagram, next page.) The rulers of Alexandria employed a group of professional pacers — men whose job it was to walk from one place to another in the kingdom counting their steps, so Eratosthenes was able to give a number for the radius of Earth — 250,000 "stades." The "stade," or "stadium" was a unit of length in the ancient world, but unfortunately, there were several different stades in common use — Egyptian, Roman, and so on. This produced one of those interminable squabbles among scholars as to how accurate Eratosthenes's result was, but using the most generous interpretation, he got a value of

29,000 miles for Earth's circumference (compared to the actual value of about 25,000 miles).

Greek astronomers didn't have telescopes, so the best they could do on the measurement of angles, as estimated by Hipparchus, was seven minutes of arc (that is, 7/60 of a degree). Given that measuring accuracy and that the baseline had to be less than the diameter of Earth, there is no way that Hipparchus could have measured the distance to the sun. In fact, he said as much in his work and said that the sun had to be no less that 490 Earth radii from Earth. (This lower bound is only about 1/50 of the actual distance). Although Hipparchus is known for having produced the first accurate star map, there is no record that he ever attempted to find out how far away the stars were. That's just as well, for it clearly would have been a fool's errand.

To measure the distance to a star by parallax, astronomers had to do two things. First, they had to get instruments that could measure angles more accurately than the eye (which in practice meant good telescopes), and then they had to find a longer baseline.

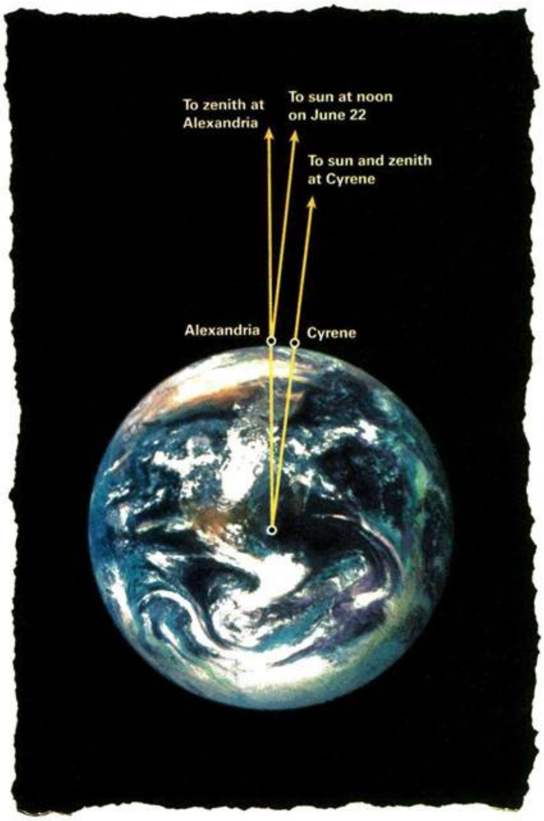
It may come as a surprise, but you don't have to journey into space to get a larger baseline than Earth's diameter. Earth itself does a pretty good imitation of space travel as it speeds around the sun during the course of a year. So one candidate for a longer baseline is the size of Earth's orbit. You would, for example, take measurements of a distant object in July and January and play the parallax game. But this leads to a kind of Catch-22 situation. To measure the distance to the stars you need to know the distance from Earth to the sun, but you need to be able to measure that distance using Earth's radius as the baseline. This means that before you could measure distances to stars, you needed to measure angles more accurately.

In 1672, the French Academy sent an expedition to Cayenne in French Guinea to make measurements of the position of Mars at the same time measurements were being made in Paris. (The logic here was this: From Kepler's laws of planetary motion, the relative distances between the sun and the planets were known. Therefore, measuring the distance from Earth to any other planet would determine the distances from the sun to all the planets as well.) Astronomers had at their disposal telescopes capable of measuring to within several seconds of arc (an arcsecond is 1/3600 of a degree) and actually came within about 10 percent of the current accepted value of the distance to the sun, or astronomical unit (AU). Today, astronomers measure interplanetary distances by bouncing radio signals off neighboring planets and measuring the time of flight.

Unfortunately, the expansion of the baseline in and of itself wasn't enough. The distance to the stars is so great that astronomers had to wait until the early 19th century for telescopes improved enough to measure stellar parallax.

What would you expect to see if you observed a nearby star against the background of more distant stars over the course of a year? Assume that the orbit of Earth is a perfect circle. If the star in question is on a line drawn through the sun perpendicular to the plane of Earth's orbit, then over the course of a year the star would appear to execute a circle in the sky. If, however, the star were located in the plane of the orbit itself, it would appear to move back and forth horizontally. If it were located between these two extremes, it would appear to execute an ellipse whose exact dimensions depend on the location of the star. Thus, what astronomers had to do was watch a given star for a period of a year and trace out differences in the angle associated with its line of sight.

By the early part of the 19th century, telescope technology had advanced so that it became possible to look for this effect. This appears to have been one of those scientific advances in which a certain amount of national pride was involved, and several teams of astronomers found themselves in a kind of race to produce measurements. Think of this as being analogous to the "races" between CERN and Fermilab to find new particles today.

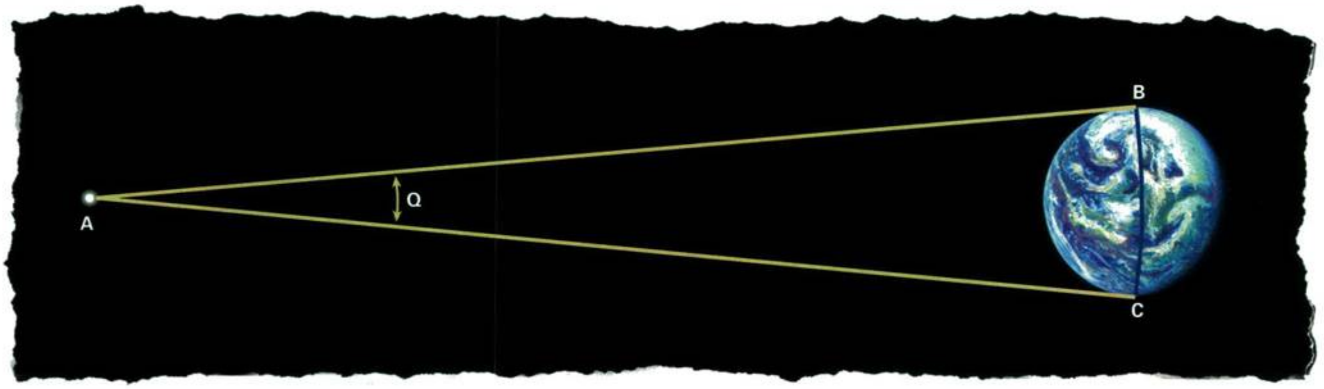


Eratosthenes, an ancient Egyptian astronomer, figured out that the distance from Alexandria to Cyrene, Egypt, was 1/50 of the Earth's circumference. On the first day of summer, he noticed that sunlight placed Cyrene on a direct line from the center of Earth to the sun. At the same moment in Alexandria, the sun's rays made an angle with the vertical equal to seven degrees or 1/50 of a circle.

The winner of this race was Frederich Bessel. Bessel is best known today for the development of the mathematical function that bears his name — the function that is a solution for the equations that describe many kinds of phenomena in cylindrical coordinates. In 1838 he published the results of 18 months' worth of precise measurements of the star 61 Cygni made at his observatory in Königsberg (now Kaliningrad). Using telescopes accurate to 0.02 second of arc, he reported a distance to this star of 690,000 AU, or 10.9 light-years — within experimental error of the currently accepted value. Within a year of Bessel's publication, F. G. W. Struve in Russia (measuring the star Vega) and Thomas Henderson in South Africa (measuring Alpha Centauri) reported similar measurements.

With Bessel's measurement, we began to sense the immense size of the universe we inhabit. If Earth were a few city blocks from the sun, for example, the nearest star would be a continent away. Clearly, our own neighborhood is pretty small stuff compared to the vastness of space. After all, the distance to the nearest galaxies is only 20 times the size of the Milky Way, while the distance to nearby stars is 100,000 times the distance between Earth and the sun.

Even after Edwin Hubble found the distances between galaxies, the problem of adding a third dimension continues to bedevil astronomers. One of the major controversies in modern cosmology involves differing measurements of the age of the universe. Although this problem seems to be headed toward an amicable solution at the moment, not too long ago, some groups of astronomers contended that the universe was younger than the age other astronomers assigned to the oldest stars — clearly a recipe for disaster.



The distance to a star or planet (A) from Earth can be determined by triangulation, if you can determine the length from B to C and the angle Q.

The disagreement revolved around the difficulty in determining the distance to far galaxies. Hubble was able to determine the distance to nearby galaxies because he was able to isolate individual stars in them, particularly stars called Cepheid variables. The light these stars give out goes through a regular fluctuation, getting bright, then dimmer, then bright again over a period of weeks to months. A number of Cepheid variables are close to Earth, and for these stars, astronomers had established that the period of the Cepheid (that is, the time it takes it to go through a bright-dim-bright cycle) is proportional to the absolute intensity of the star (that is, the amount of light that the star gives out). Knowing the amount of light a Cepheid variable was actually emitting and comparing it to the amount of light that he actually received at Mount Wilson, Hubble was able to determine the distance to nearby galaxies. The technique of establishing the relationship between the intensity and the period for nearby Cepheid variables and then using that relationship to measure much greater distances is what is known as assembling the "astronomical distance ladder."

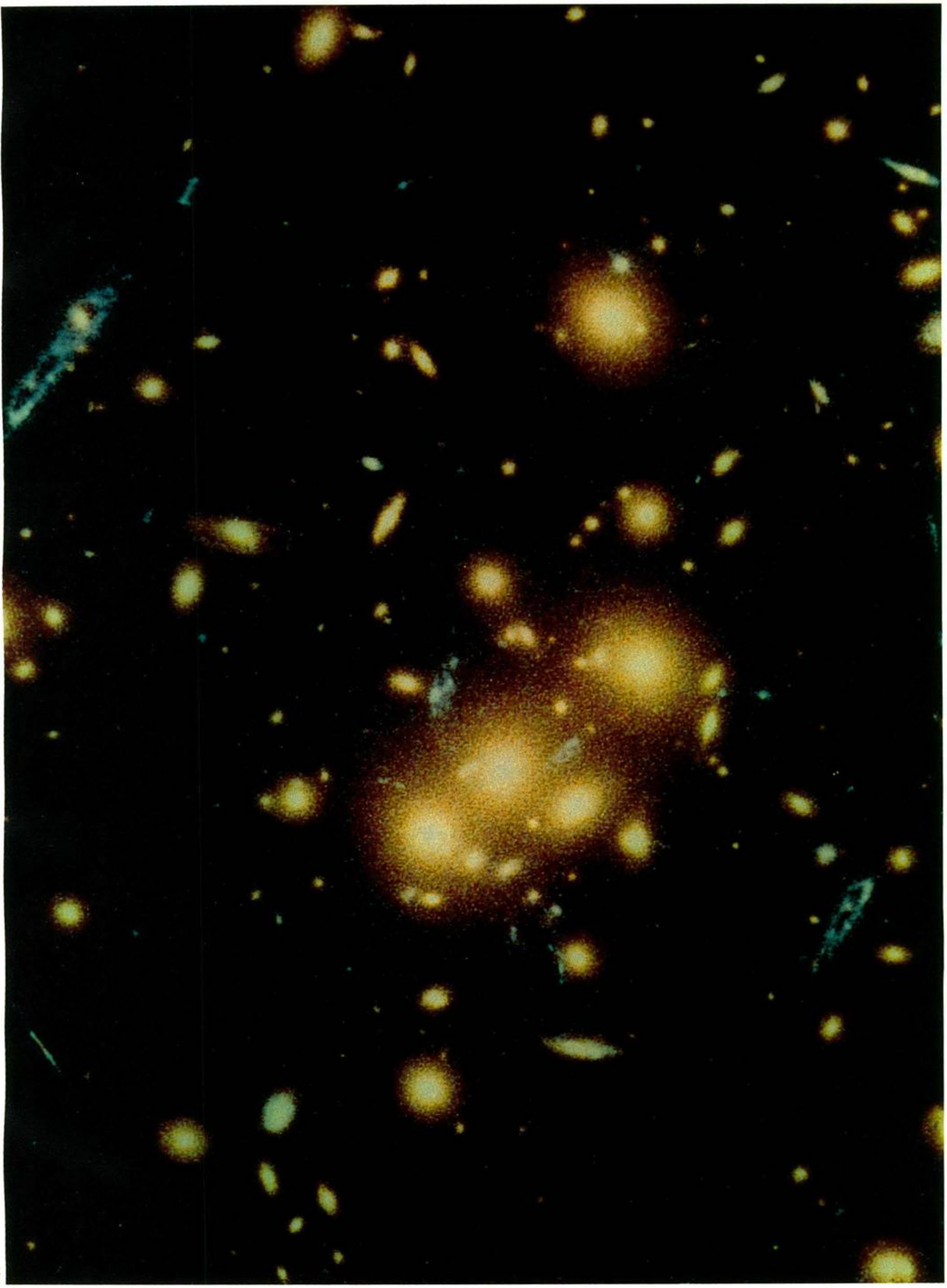
Part of the argument over the age of the universe arose due to uncertainties in the distances from Earth to nearby Cepheid variables. Because these distances are crucial in establishing the distance ladder, any errors made in measuring them get multiplied as the ladder is pushed out into the universe. None of these distances can be measured by parallax, so extra steps are introduced into the lower rungs of the astronomical distance ladder.

In 1989 the European Space Agency launched a satellite called HIPPARCOS. During its brief and troubled lifetime (the satellite stopped transmitting in 1993), HIPPARCOS performed the first accurate parallax measurements of nearby Cepheid variables, producing a vastly more accurate yardstick by which to measure intergalactic distance. It could do this because it was capable of measuring angles to a thousandth of an arcsecond (i.e., one thousandth of 1/3600 of a degree). These new measurements could then be used to re-calculate both the expansion rate of the universe and the age of the oldest stars. The universe and the oldest stars are a little younger than most people had thought, although not as young as some people had argued. It appears that we are headed for a compromise on the age of the universe of about 12 billion years.

The story of parallax is really the story of humanity's understanding of the universe in which we live and of the relative insignificance of Earth and the sun in that universe. Each successive measurement that allowed us to increase the baseline or measure angles better pushed the limits of our universe farther away. And in this grand chain of accomplishment, that day in Germany in 1838 when Frederich Bessel first measured the distance to a star stands out as a crucial milestone.

James Trefil, the Robinson Professor of Physics at George Mason University, a science commentator for National Public Radio, and a prolific writer, is a member of Astronomy*'s Editorial Advisory Board.*

The last rung on the distance ladder uses the redshift of distant galaxies, such as those in the massive cluster 0024+1654, a gravitational lens that creates the bluish arc-like images.



HST

KECK *Trekking*

The Keck Telescope, the world's largest, is shaking up astronomers' notions of the universe.

text by Julie Wakefield, photographs by Philip Rosenberg

As I set off from leafy Kamuela, Hawaii, in a monster, nine-passenger Chevrolet Suburban with a heavy-duty suspension, a rare bank of clouds conceals my destination: the nearly 14,000-foot volcanic summit of Mauna Kea. My arms work the steering wheel as I ascend 48 miles of narrow, curvy paved roads. Nearly two hours later, I pass the clouds and tree line to survey a bleak terrene of black and rust-colored cinder cones. It's freezing. If not for the road and a thin remnant of an oxygen-containing atmosphere, this could be Mars.

Further on I see a scattering of more than a dozen white telescope domes, including the $180-million Keck I and Keck II twins of the W. M. Keck Observatory. Each has a 10-meter mirror, the largest in the world. In the distance, a lava vent glows red. I think to myself that this is a fitting outpost for Earth's most powerful portal to alien worlds.

Each of the Keck twins has the ability to detect and dissect very faint visible and infrared light emanating from the most distant astronomical objects in the universe. Star light is loaded with information and Keck astronomers extracting that information are shaking up long-standing notions about fundamental processes, like the origin of solar systems and galaxies. Mauna Kea is astronomy's Olympus, its scientific pinnacle; however, something is missing — the scientists.

Astronomers no longer endure the mountain's freezing fogs, its snow storms, its otherworldly thin air, and its isolation. They overturn astronomical pineapple carts at lower altitudes while wearing short-sleeve shirts and sandals. The summit of Mauna Kea may be ideal for spotting specks of light from distant galaxies, but the altitude also causes headaches, confusion, short-term memory loss, and sometimes more severe symptoms.

After touring the observatory I drive back down the mountain and look for astronomers to arrive at the Keck "observing room" in Waimea. These headquarters are part high-technology, part historic Hawaiian ranch. The neighbors include some 50,000 cattle grazing the 250,000-acre Parker Ranch. After dusk, I find Steve Vogt, an astronomer with the University of California at Santa Cruz. He and the mountain-top observatory crew are communicating via a fiberoptic connection and two-way television cameras as they prepare to point Keck I. (Kecks I and II are so similar that most astronomers, whether using I or II, refer to them in the singular simply as "the Keck.") The sky is cooperating. "This is some of the best seeing I've seen in a long time," says Vogt, pleased with the now clear, balmy evening. On a good night, the telescope can distinguish objects that are 0.3 arc-seconds apart, which is comparable to distinguishing two M&Ms from 6 miles (10 km). "It doesn't get much better than this," he says, waiting for his first target to appear on a video monitor.

"I bet this is going to come in blazing," agrees Geoffrey Marcy, Vogt's partner and his former graduate student — now a member of astronomy's most successful extrasolar-planet-hunting team. Marcy and Paul Butler, of San Francisco State University and the University of California at Berkeley, have discovered five of the six extrasolar objects confirmed, as of

The Keck I dome blushes at sunset before a night of viewing.

tonight, to be planets orbiting sun-like stars. They made their discoveries during the past two years at the Lick Observatory in California, and they plan to apply the techniques they learned there while using the Keck.

THE LUCKY ONES

Butler and Marcy consider themselves lucky. Only a couple dozen astronomers a year use the Keck. Six proposals are rejected for every one accepted, and that's after the scientists have run the grant-application gauntlet. "I really feel this effort is the most important thing going in my life, though my wife might not like to hear me say that," Marcy says. "This project is, in a sense, who I am."

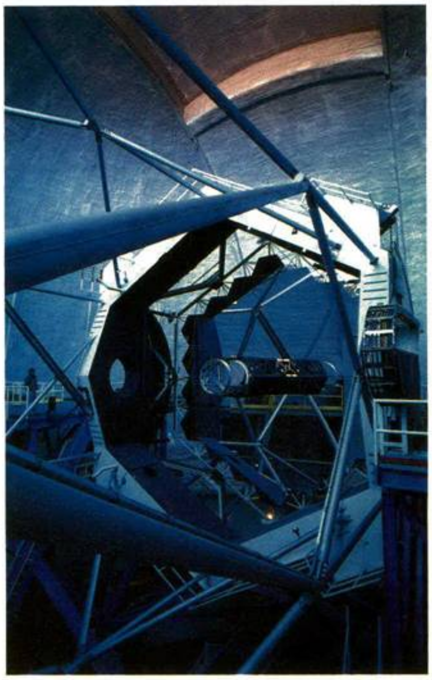
Marcy wants to be doing nothing else on Earth at this moment than collecting light and extracting whatever information he possibly can from it. However, he says even the mighty Keck is unable to extract all the many kinds of information contained in the light arriving from their sources. "It's such a treasure even to have access to it," he says. "I just can't imagine doing anything other than squeezing out all the wonderful astronomical knowledge that you can possibly get from it."

Extrasolar planets themselves are too dim for any telescope to distinguish. (TMR-1C, an object recently spotted by the Hubble Space Telescope near a binary-star system, may be a Jupiter-sized planet.) What little light they do emit is lost amid their parent stars' brilliant glare. Yet, the planets can be detected indirectly. Marcy and Butler deduce the planets' presence by watching stars move: If a star has a gravitationally bound planet, the star moves toward it, or wobbles, as the planet orbits. If the wobble occurs along our line of sight, the wavelengths of its light shorten when it moves toward us and lengthen when it moves away from us. In the process, its light changes wavelength in a regular rhythm — toward the blue or shorter wavelengths, and then toward redder, or longer, wavelengths. It is the most subtle signature of a planet.

"We can cook," Marcy announces to the television monitor.

Marcy's first target tonight is star HD 207804, one of dozens of stars he hopes to scan before dawn. At the operator's command, the eight-story, 300-ton telescope slowly turns and points at HD 207804 with a pointing accuracy within one-billionth of a meter. Within minutes of Marcy's verbal go-ahead, HD 207804 appears on his video monitor: It is a black dot on a light background.

The data collected by the observatory will be dissected and calibrated later through computer programs devised by Marcy and Butler. Months of analysis and perhaps more observations over several years may be needed to determine whether a given star with a wobble is actually wobbling because of a planet.



ABOVE: Icy mists deposit hoary frost on a mountaintop front-end loader.
LEFT: The Keck I primary mirror is a mosaic of 36 reflective segments.
FAR LEFT: The volcanic foothills of Mauna Kea are home to thousands of cattle.

KECK'S ELECTRONIC CAMERA

Each of the Keck's primary mirrors is made up of hexagonal segments. Tracking gears and computer hardware and software do the pointing. Light detectors, called charged-coupled device (CCD) cameras, are important as well. A CCD looks like a flat plate and is made up of tens of thousands of tiny electronic photoreceptors, or pixels, that count the light photons it receives. "It's a very complex counting game that goes on among these bins of light to detect if these stars have moved," explains Vogt. He spent eight years designing a refinement of the detector — a high-resolution spectrograph, the largest and most precise of its kind in the world. The spectrograph records the number of photons received by each pixel and the spectrograph spreads the star light received by each pixel into its component wavelengths. The result is called a spectrum. The spectra, which can look like bar codes on cereal boxes, identify the source of the light as coming from hydrogen, helium, lithium, iron, or other elements and chemical compounds. Spectra "fingerprint" a star or other light source.

Ever since the discovery in 1929 by Edwin Hubble that the more distant galaxies are from Earth, the faster they are traveling away from us, spectra tell a bigger story. The faster a galaxy is traveling away from us, the more its spectrum is Doppler shifted to longer, or redder, wavelengths. The so-called redshift occurs in proportion to how fast the object moves away from us. The actual numerical value of the redshift (also called the z value) is an important astronomical statistic. For example, light received from a very distant galaxy with a redshift, or z, of 3 will have the wavelengths of light in its spectral fingerprint shifted to higher values by a factor of 4 ($z + 1$).

If a picture is worth a thousand words, "a spectra is worth 1,000 pictures," says astronomer Sandra Faber at the University of California at Santa Cruz. "Keck," she says, "excels at spectra." Although spectra may not dazzle viewers the way images from the Hubble have, the Keck's contributions are crucial, says Faber. "And the Keck goes fainter spectroscopically and imagewise than any other scope," she adds.

KECK'S SPACE PARTNER

Unfortunately, the images produced by the telescope are not as sharp as those produced by the Hubble's 2.6-meter mirror. And the Hubble's position, above Earth's light-scattering atmosphere, gives it advantages over ground-based telescope. However, because each Keck mirror has about 14 times the light-gathering area of the Hubble, each one can gather photons 14 times faster than the Hubble. That advantage, combined with Keck's superb instrumentation and relatively "smooth" air above the Pacific Ocean contribute to extraordinary viewing.

Even before the movie version of Carl Sagan's novel *Contact* was filmed, the search for extraterrestrial worlds was a scientific priority. NASA is planning to fund astronomers' attempts to survey 300 to 400 stars during the next 10 years.

"What we'd all like to find orbiting another star is something that's very much like Earth," says Marcy. "Or similar to Earth, so we can hold that star up like a mirror and learn about our own solar system and our Earth."

In meeting such challenges, the Hubble and the Keck are members of an unbeatable team. For example, after the Hubble released its two-dimensional Deep Field image of infant galaxies in the early universe, Keck provided redshift data on those galaxies, supplying the crucial third dimension: depth. "Most popular articles about these new discoveries almost always mention both of them because there's this wonderful synergy between the two," explains Keck director Frederic Chaffee.

To speed up the process of determining redshifts, Faber and her colleagues are building an instrument for Keck that can take spectra of 100 galaxies simultaneously. Once each galaxy's redshift is determined, Faber explains, astronomers can use spectra to determine its mass, age, luminosity, and other characteristics.

Analyses of the three-dimensional distribution of galaxies may answer key questions about how the first structures formed after the Big Bang and how galaxies form, evolve, merge, and distribute themselves.

About 10 percent of the Keck's time is devoted to quasars, mysterious lighthouse beacons found at great distances from Earth. Light from quasars, the brightest objects in the universe, shines through intergalactic space and this light can be absorbed by intervening gas before it arrives here. Absorption spectra can explain such events as the collapse of clouds of gas into stars and the birth and evolution of galaxies. "In many ways the Keck telescopes have cornered the market on quasars," Chaffee says.

GALAXIES ARE NOT UNIFORM

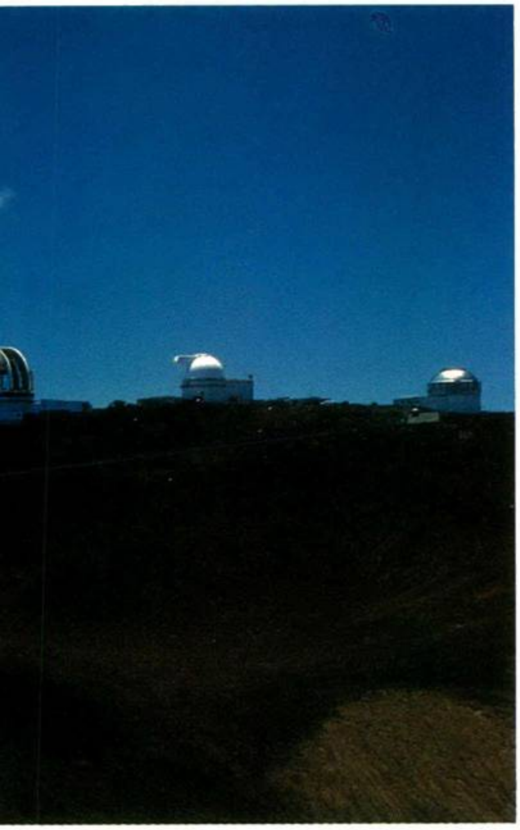
The Keck also excels at studying galaxy formation. Astronomers using the observatory have found differences between galaxies in the middle-aged universe and galaxies as they exist now. While large galaxies have not changed much, smaller galaxies show dramatic development, Faber says. "This suggests galaxies evolve at different rates depending on size."

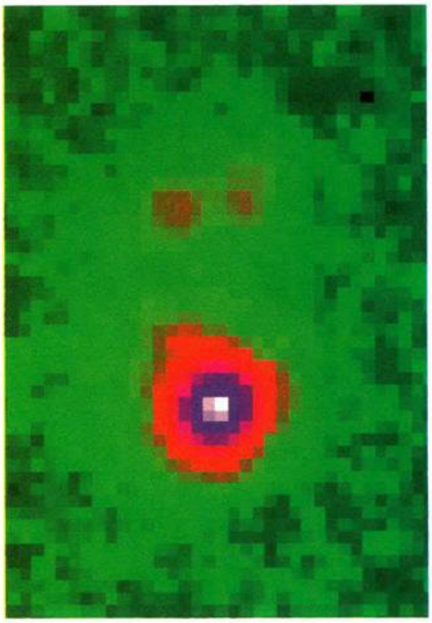
Several astronomy textbooks published in the 1980s and early 1990s say that most galaxies probably formed at about $z = 3$. But the Keck recently has discovered infant galaxies at redshifts of 5 and greater, or within a few percent of the Big Bang.

"They are very probably galaxies forming for the first time," says Faber, ". . . Tiny shreds that will merge with other bits and pieces to make the big galaxies we see today." Few, if any, cosmologists would have predicted publicly only a few years ago that the galaxies could possibly have formed so soon after the Big Bang.

HUNTING FOR BIGGER WOBBLES

The University of California at Berkeley's Alex Filippenko has used Marcy and Butler's planet-finding technique of stellar-wobble detection to search for black holes. These objects form after massive stars run out of fuel and explode as supernovae: Left in place of these stars are regions in space from which nothing can emerge because their gravitational forces are so strong. Black holes are the 800-pound gorillas in the cosmic jungle that burp powerful x rays, called gamma rays, as they devour neighbors unfortunate enough to be too close. Stars farther away are gravitationally jerked. "The wobble is much larger in the case of stars orbiting black holes," says Filippenko. "It is hard to detect because the stars themselves are so faint."





Robert Pina & Charles Telesco, University of Florida

ABOVE: Skiers take on a snowy cinder cone.
LEFT: Keck II picks out several supergiant clusters with huge populations of young stars embedded in the ultraluminous galaxy Arp 220.
FAR LEFT: The Keck I and II domes are flanked by, from left, the NASA Infrared Telescope, the Canada-France-Hawaii Telescope, the Gemini Telescope, the University of Hawaii Telescope, and the United Kingdom Infrared Telescope.

Black hole hunters like Filippenko increase their chances of success by examining the motion of x-ray emitting star systems. Such systems tend to be rare, distant, and faint. "Thus," says Filippenko, "we need the light-gathering power of Keck to get their spectra."

So far, astronomers have evidence of nine stellar-mass black holes in our Milky Way galaxy, three of which were found with the Keck by Fileppenko and his colleagues. Astronomers have also found strong evidence of supermassive black holes that are a million to a billion times more massive than our sun in medium and large galaxies.

A DOLLAR A SECOND

Meanwhile, back under the starry Hawaiian sky, Vogt, Marcy, and Butler describe their telescope work as technical, mathematical, businesslike, even tedious. At a dollar per second, time on Keck is used in a way that optimizes efficiency. "It's very unromantic," says Marcy. But the preparation pays off: In the first hour of observing tonight, the team studied 10 stars.

This year, a $7.4-million adaptive optics system will be added to the Keck to erase as many of the blurring effects of atmospheric turbulence as possible. The Keck's acuity will be further boosted with a $44-million interferometry addition to be completed in stages by the year 2003. As an interferometer, astronomers will coordinate Kecks I and II to look at the same objects simultaneously. (Multiple telescope arrays, like the 27 radio telescopes of the Very Large Array in New Mexico, function as interferometers.) Light received by Kecks I and II will be combined so that the peaks and valleys of wave fronts arriving at the same time at each telescope will be combined: Two wave peaks arriving simultaneously will be added together and a peak and a valley will cancel each other. The effect will be the equivalent of one telescope that will behave as if it had an 85-meter mirror. (This is the distance between Kecks I and II.) The interferometer will be critical for mapping galaxy morphology and motion and for analyzing the dynamics of the universe.

Keck is king and future discoveries can only be imagined. "The exciting things in astronomy are the things you just didn't anticipate because you didn't have the technology to do it before," says Keck director Chaffee. "If you knew what you were going to find, you wouldn't build a telescope." ▣

Julie Wakefield is a freelance writer based in Washington, D.C.

POLICING THE UNIVERSE

All newly discovered comets and asteroids have one thing in common: Brian Marsden.

by **David H. Freedman**

The phone rings, and Brian Marsden can only ignore it for two long jangles before snatching up the receiver with a sigh. "What sort of bodies did you have in mind?" he says, after listening for a moment. And then, with measured patience: "Well, we generally don't deal in stars around here . . ."

The conversation may bring to mind an escort service, but Marsden is a different sort of middle man. As director of the International Astronomical Union's Central Bureau for Astronomical Telegrams and the Minor Planet Center, Marsden is — at least with regard to comets, asteroids, novae, and supernovae — the gatekeeper between raw astronomical observation and astronomical record, if not immortality. A flood of data pours into Marsden's office, coming from the rankest amateurs to cutting-edge Big Science teams. What emerges are the prosaically elegant IAU *Circulars* that are distributed to astronomers all over the world and more or less officially list orbits and discoveries. "If it moves or it's fuzzy, it goes through us," he says.

Headquarters for these activities is a cramped, tiny office in the Smithsonian Astrophysical Observatory, located on the periphery of Harvard University in Cambridge, Massachusetts. All of the office's horizontal surfaces, including the chairs, are spectacularly cluttered with thick binders and vast towers of loose papers, any one piece of which Marsden is liable to deftly pull out and brandish at a visitor to support his uncanny powers of recollection.

There's quite a lot to recollect. When Marsden took over the directorship of the Central Bureau in 1968, discoveries came in by mail, teletype, and occasionally by telegram. The office's teletype machine was hauled away in 1988, and the only telegram of importance that has made its way to the office in this decade was the one Thomas Bopp sent in 1995 to report his discovery of a comet. Now, of course, e-mail is the communication medium of choice (including that of Alan Hale, whose e-mail note about his comet discovery arrived a couple of hours ahead of Bopp's telegram).

Some 20 or so batches of e-mailed reports flow in on a typical day, some batches listing the coordinates of as many as 5,000 objects that have meandered through or popped up in star fields. The coordinates of these objects are compared to the known orbits of asteroids and comets. If there's a match, the data go to refining these orbits. If a link to known objects can't be found, then, upon verification by further observation, Marsden eventually declares it a discovery, and the object is given an official designation. In the case of a comet, the discoverer's name becomes a second moniker.

The number of newly discovered asteroids has risen dramatically in recent years, thanks to several sky-survey projects using CCDs. Three of the biggest include the Jet Propulsion Laboratory's Near-Earth Asteroid Tracking project, the MIT Lincoln Laboratory's Near-Earth Asteroid Research project, and the University of Arizona's Spacewatch program. In a recent month, 67,000 observations made it into the records, resulting in the discovery of more than 3,000 new asteroids. That's more than seven times as many new ones as turned up in an average month in 1990, and about 65 times the rate in 1970. Due to new surveys that peer deep into the universe, supernova sightings in 1997 reached 163 — nearly twice as many as the 92 found in 1996, the previous record holder.

Chubby, ruddy-faced, adorned with a halo of thinning, comb-resistant gray hair, Marsden shows no signs of being overwhelmed. Speaking in ebullient bursts of precise monologue, punctuated by an occasional stammer of enthusiasm, the 61-year-old astronomer recalls how as a high school

Jon Chase

student in his native England he became one of only a handful of people worldwide willing to take on the chore of calculating initial orbits of newly observed comets. He was armed only with a massive table of seven-figure logarithms and a bulky mechanical calculator, which he lugged from the home of a member of the British Astronomical Association to his home in Cambridge, England.

After obtaining his undergraduate degree at Oxford, Marsden hopped across the Atlantic in 1959 to enroll in Yale's highly regarded celestial mechanics program — just as the program was becoming one of the beneficiaries of the U.S. government's determination to wipe out the Soviet Union's space exploration lead established by Sputnik in 1957. "I was interested in orbits. There was nothing going on in England at that time, and at Yale there was a school in this," recalls Marsden.

Shortly after his marriage to Nancy Zissell in December 1964 and upon obtaining his Ph.D. in 1965, Marsden accepted an offer from Fred Whipple, director of the Smithsonian Astrophysical Observatory — another hotbed of post-Sputnik activity, thanks to its satellite-tracking program — to join him at the Smithsonian. Three years later, he succeeded Owen Gingerich as director of the Central Bureau for Astronomical Telegrams, which had moved to the Smithsonian in 1965 after 42 years in Copenhagen, Denmark. In 1978 the Minor Planet Center, which had been based in Cincinnati, Ohio, also jumped to Cambridge, Massachusetts, and to Marsden.

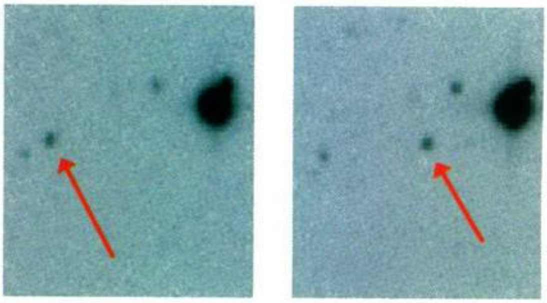
James Scotti (University of Arizona)

When Alan Hale and Thomas Bopp co-discovered the comet that bears their names, Marsden's office spread the news. Soon thereafter, scores of amateur and professional astronomers were photographing the comet. This photo was taken on August 1, 1995, nine days after the comet's discovery.

Besides running the Central Bureau and Minor Planet Center, Marsden has kept his hand in research. His goal is to help achieve a comprehensive "inventory" of the solar system. In particular, Marsden has had a strong hand in encouraging, and in personally interpreting the resulting data from, observations of the various objects in the outer solar system, including the comet-like denizens of the Kuiper belt. Marsden has been one of the most vocal proponents for reclassifying diminutive Pluto as a "minor planet," pointing out that it's just the largest known Kuiper belt member. "Calling it a planet is confusing to school children. It doesn't belong out there with the giant planets. We're much better off considering the solar system as four giant planets, four terrestrial planets, asteroids, and icy objects in the outer solar system," he says.

Though the volume of data coming through his office has exploded in the past decade, Marsden insists the last thing he wants is an expanding bureaucracy to help him deal with it. "It's nice that we've remained small," he says. "When you get big, you start to have all kinds of troubles."

He isn't working single-handedly, of course. Thanks to ever-growing reservoirs of automation and cooperation, the processing and posting of observational data has reached levels of efficiency that were inconceivable even a decade ago. Marsden's assistant Gareth Williams does much of the data crunching on asteroids, feeding the raw observations into software he himself has perfected, producing more than 2,000 minor planet circulars per year. A second assistant, Dan Green, is largely responsible for the 300 or so one-page IAU *Circulars* sent out each year. Also making life easier is the fact that those working on large sky-survey projects do a certain amount of pre-processing of their data to eliminate bogus sightings before submitting the results in the morning. And a sort of virtual global astronomy team has emerged around the world to help verify and build on initial observations.



James Scotti and Jeff Larsen

When James Scotti of the University of Arizona's Spacewatch program discovered asteroid 1997 XF_{11} in these December 6, 1997 images, it seemed harmless enough. But Marsden's calculations, based on additional observations, initially indicated that the one-mile-wide asteroid had a slight chance of smashing into Earth in 2028 and causing global catastrophe.

Still, keeping up with the universe is no easy task for three people. Marsden semi-seriously refers to the "sweat shop" working conditions. "I don't have much time for outside interests. I'm working on two books at the moment, but they never seem to get anywhere. Gareth cannot take a single day off."

Consider the complex choreography that comes into play on a typical morning when JPL gathers NEAT's observations from the previous night. By noon Pacific Time, JPL has finished preprocessing data and e-mails the coordinates of likely asteroid sightings to Marsden's office, where it is 3 p.m. Williams runs the data through his software, making the links to known minor planets and identifying any apparent discoveries. The coordinates for possible discoveries are posted by 4 p.m. Eastern Time on the Bureau's website, where they have been eagerly awaited by astronomers in post-sunset time zones. In particular, two separate Czech teams have long committed themselves to verifying preliminary sightings. ("It's the country with the most per capita support for this kind of work," explains Marsden.) By 6 p.m., the Czechs and others are reporting back, allowing Williams to post the verified discoveries on the web before leaving for the day. "The key is organization," says Marsden.

Too bad the job isn't always that easy. Marsden also has to contend with a steady stream of unreliable or difficult-to-process data. Some of it comes from well-meaning but inexperienced amateurs who don't properly format the data they submit, stymieing Williams's software. Some of it comes from careless, hair-trigger observers, like the fellow who on a nearly monthly basis reports the discovery of a new comet that no one else can ever verify. Some of it is from painfully naive sorts, like the man who phoned in to urgently report the sighting of a "fuzzy object" keeping Comet Hale-Bopp company. "He seemed quite offended when I told him that he could look up any of thousands of pictures of Hale-Bopp on the Web," recalls Marsden. And some amateurs and professionals still try to submit rough observations, lacking precise coordinates of observed objects, though Marsden accepts them only from amateurs who make visual discoveries. "There's a greater

CRYING WOLF?

"This nominal orbit indicates that the object will pass only 0.00031 AU from the earth on 2028 Oct. 26.73 UT! Error estimates suggest that passage within 0.002 AU is virtually certain . . ."

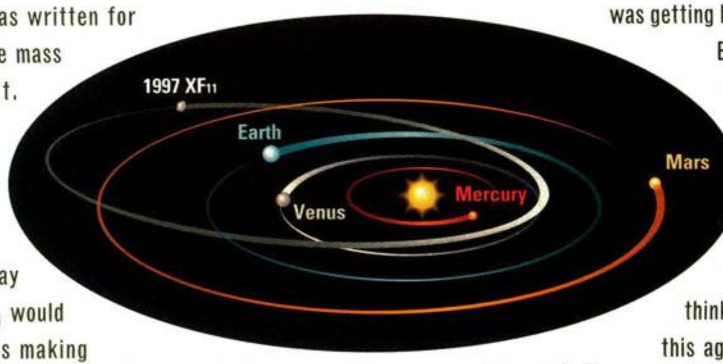
Little did Brian Marsden know that these seemingly innocent sounding words — from a March 11, 1998, IAU *Circular* — would spark a worldwide media frenzy and scathing criticism from some of his peers. He was referring to near-Earth asteroid 1997 XF_{11}, discovered three months earlier by James Scotti of the University of Arizona's Spacewatch program. Based on the available data, Marsden's initial calculations showed that the one-mile-wide asteroid could pass within a hair-raising 30,000 miles (0.00031 AU) of Earth on October 26, 2028. But there was a large uncertainty in the asteroid's orbital path. "In more than 40 years of computing orbits, I had never seen the indication of such a close approach. It seemed not out of the question that this asteroid would hit Earth. We needed to ask for further observations," explains Marsden.

While the IAU *Circular* was written for professional astronomers, the mass media quickly jumped on it. Despite reassuring words from Marsden and calculations by other astronomers that the asteroid would definitely miss Earth, within a day the possibility that 1997 XF_{11} would cause Doomsday in 2028 was making front page news all over the world.

Marsden's *Circular*, however, had the intended effect of spurring astronomers to sift through their old observations. Astronomers at the Jet Propulsion Laboratory quickly found photographs of the asteroid taken in March 1990. With two additional positions in hand, Marsden refined the asteroid's orbit and determined it would miss Earth by a comfortable 600,000 miles. "That's the way science works," stresses Marsden. "We got it right, and in less than 24 hours."

Unfortunately, in this era of instant global telecommunications, that wasn't fast enough. Embarrassed by the media fiasco, a number of astronomers harshly criticized Marsden for exaggerating the danger and for not communicating privately with other astronomers before issuing the *Circular*. Marsden objects to these criticisms, stressing that the astronomical community and the public should be immediately alerted if there's even the slightest possibility of a catastrophic impact. "I don't think it's crying wolf because these asteroids are being discovered and nothing is being done about them. We knew of this object in December and nobody had done anything, and it was getting harder to observe."

Because of this incident, Marsden is now indicating more carefully the potentially hazardous asteroids as soon as they are recognized. He has also added a new website listing their future approaches. "I don't think we'll ever have a situation like this again because of the changes that have been made and the awareness that people have toward looking at older photographs," he says. — *Robert Naeye*



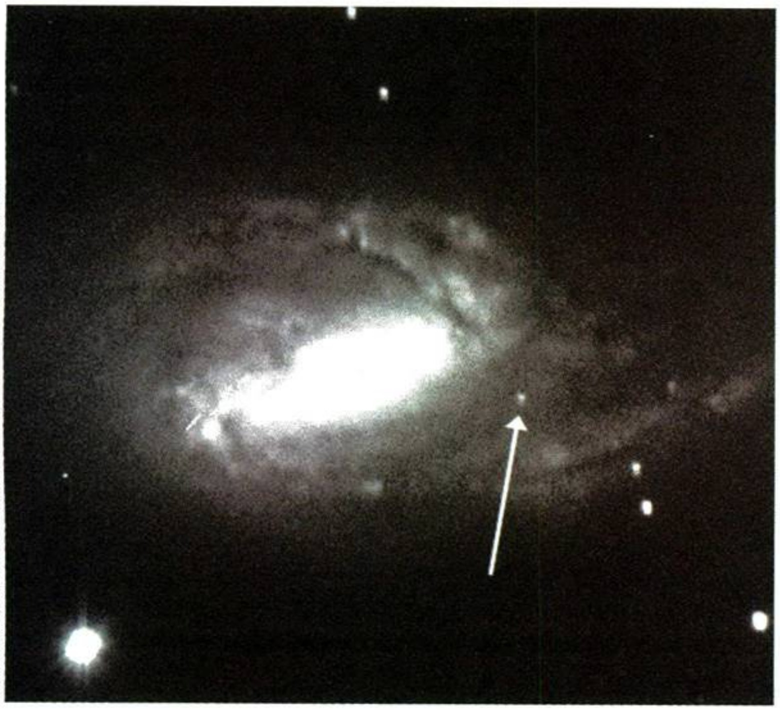
Asteroid 1997 XF_{11}'s orbit crosses Earth's orbit. The one-mile-wide body may someday collide with Earth, but not in the next few hundred years.

Astronomy: Elisabeth Rowan

strictness on our part now," he says. "We don't like having to rework the files later on."

Yet Marsden is also quick to declare he's more than happy to take the time to work with serious amateurs to help them get their data up to standard. "Actually, we encounter many amateurs who turn in beautiful observations from the very first batch. I think it's great what amateurs are doing these days with modern CCD equipment." In fact, some of the most annoying data comes from near the top of the astronomical food chain. "You'd think Palomar would have super-duper measurement devices," he says. "But we've had comet reports from them that were really quite sloppy."

Another annoyance is the tendency of many observers — both amateur and professional — to submit data based on a single night of observation. Unfortunately, most observations fall into this category, because the large sky-survey projects have too much sky to cover to train their telescopes on the same objects for two nights in a row. Williams dutifully processes the single-night observations, and those sightings that can be associated with known objects are published and used to refine orbits. But any objects that can't be linked, and thus are potential discoveries, are declared to be "one-night stands" and are put aside. That's because without the insurance of a second-night sighting, declaring a discovery runs the risk of conferring minor planethood on a ghost image, a plate flaw, or an object that is never seen again. "I don't know why people bother to send us single-night observations," says Marsden. "It's a nuisance. We just file them away with no official designations, and they're not published." Marsden's policy: A discoverer is the first person to observe an object two nights in a row.



Alexei Filippenko (Univ. of California at Berkeley) and the Lick Supernova Search Team

After professional astronomers at Lick Observatory discovered Supernova 1997BS in galaxy M66, they reported their finding to Brian Marsden at the IAU's Central Bureau for Astronomical Telegrams. Marsden announced the discovery to the rest of the world in an IAU *Circular*.

But if Marsden's job has its routines and annoyances, it also provides its share of exhilarations and challenges. These often come in the form of sightings that don't fit into neat categories. For example, there was the object that had the near-parabolic orbit of a comet and yet lacked a tail and coma; Marsden finally realized it was an asteroid in an unusually eccentric orbit. "It's not all just running the software," explains Marsden. "Judgments have to be made, and some observations are real puzzles."

One of the hardest tasks, claims Marsden, is making initial orbit calculations of newly discovered objects. That's a rather long, drawn-out process with asteroids, which usually have to be followed for two or three months before an orbit can be nailed down. But the pressure is on with newly discovered comets, whose orbits can often be roughly mapped out after the second night of observation (see Ask Astro, page 96). Marsden is particularly proud of his fast and accurate turnaround on Comet Hale-Bopp. Just one week after its discovery at the end of July 1995, Marsden correctly predicted its April 1, 1997, perihelion.

In general, comets are a more delicate business than asteroids. "They're much rarer, and unlike asteroids they're named for their discoverer, so we have to be more careful," Marsden explains. The process of officially naming comets has always engendered debate and objections, since determining who deserves to share in the credit for a comet discovery is not always a completely cut-and-dried matter. In particular, the question of how many people should have their names appended to that of a new comet has been a thorn in Marsden's side. "Two names are plenty," he says. "You might have a team of five people running an observatory, but it only takes one of them to actually make the discovery. Up to a point you can argue that it involves two people, but a triple-barreled name is too much, and four names is ridiculous. If a team can't decide which one or two people deserve the credit, then they can give the comet a group name."

Comet Hale-Bopp, fortunately, didn't involve much wrangling over names, having been cleanly,

STAKING YOUR CLAIM

If you think you've spotted a new asteroid, comet, nova, or supernova, instructions on how to submit your discovery claim can be found at the following website: http://cfa-www.harvard.edu/cfa/ps/cbat.html. Remember that each month the Central Bureau for Astronomical Telegrams receives discovery claims of comets, novae, and supernovae that turn out to be non-existent. The Central Bureau does not look favorably on astronomers, amateur or professional, who habitually report false discoveries. — R. N.

Jon Chase

separately, and more or less simultaneously observed and reported by the eponymous Hale and Bopp. However, Marsden notes that the comet might well have been discovered as far back as 1993 — if the team that took what appears to be its picture had more than one photographic plate. "Damned nuisance, those single plates," scoffs Marsden.

If comet-naming is less of a worry these days to Marsden, then the slack has been taken up by the increasingly shaky finances of the two organizations. Oddly, the two chief culprits are the very things that the Bureau might be the most proud of: the ever-increasing volume of sightings it handles and the ability to post information quickly on the Web. "Preparing the material is taxing our computers to the point where we need some help handling them," Marsden explains. "And since everyone can obtain the information for free on the Web, there isn't as great a demand for the *Circulars*." With the number of $9-per-month *Circular* subscriptions declining to half of what they were, operations are in danger of going into the red.

One solution Marsden toyed with: charging the large sky surveys the cost of processing their observations. "Why shouldn't we be an overhead on the observing process?" he asks. "Without us, the observations are useless."

But there's no talk of charging amateurs, whom Marsden clearly considers the soul of the entire astronomical-object-finding process. Not that his patience is infinite. As his phone rings yet again, he glares at it suspiciously. "Some of these amateurs are quite stubborn," he mumbles. "Once in a while I take the phone off the hook." Then he picks it up and greets another would-be discoverer. ■

David H. Freedman is a contributing editor to Discover *and* Forbes ASAP. *His new book, co-authored with Charles C. Mann, is* @Large: The Strange Case of the World's Largest Internet Invasion *(Simon & Schuster).*

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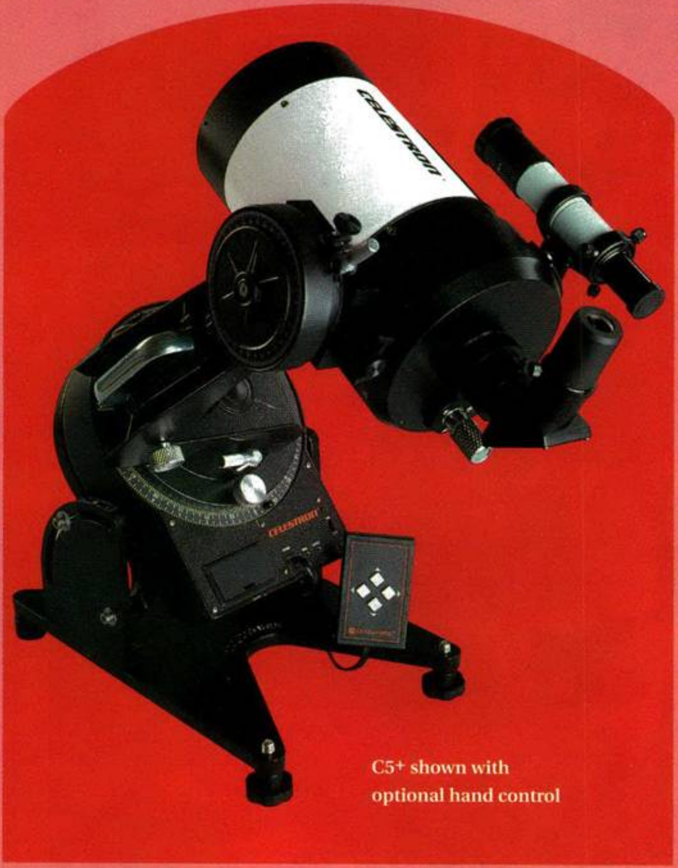

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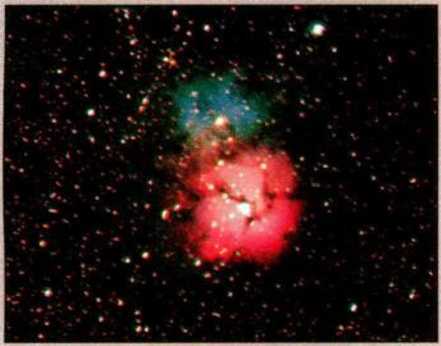

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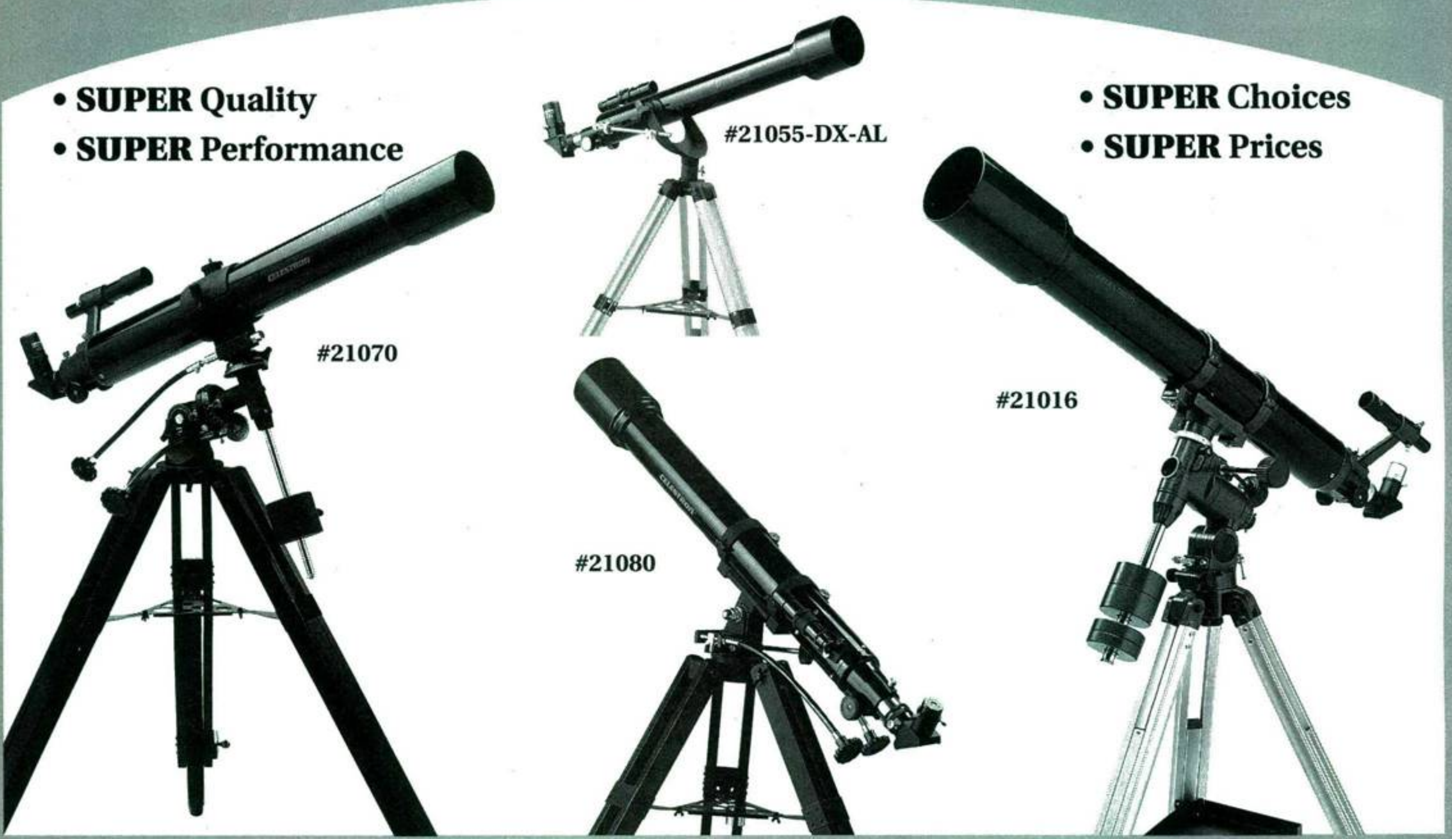

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C114-HD
#31056
C150-HD
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Firstscope
114 Deluxe

• Sturdy Equatorial and Altazimuth Mounts • Size Ranges from 76mm (3") through 150mm (6")

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The superb optics of these telescopes offer dazzling images of the moon; Saturn and its rings; Jupiter, with its belts and moons; and hundreds of deep-sky objects, including brighter galaxies, nebulae and star clusters.

The 114mm (4.5") Newtonian equatorial telescope is the most popular size telescope for the more serious beginning or intermediate level astronomy enthusiast, and for good reason. The large light gathering power of this 4½" telescope makes it ideal for deep-sky observation of galaxies, star clusters and nebulae, as well as lunar and planetary observing. This makes for a very useful and versatile instrument that can take an observer from the very first time looking through a telescope's eyepiece, through years of observing interesting subjects near and far in the night sky.

Celestron offers five different 114mm Newtonian equatorial telescopes, making it a sure bet that one of them will have just the combination of features and performance you're looking for.

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The C114-HD attaches to the CG-4 mount, a very rigid German equatorial mount designed for the discriminating buyer. This heavy duty 114mm Newtonian stands out from the other 114mm telescopes on the market by having by far the best mount.

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The C150-HD offers views of intriguing lunar details and high power planetary viewing. You can see detail in Jupiter's equatorial belts, the beautiful ring structure of Saturn and the polar caps of Mars. This telescopes is large enough to observe hundreds of deep-sky objects with ease, fully resolve many globular star clusters, and allow you to enjoy viewing brighter nebulae, double stars and galaxies.

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THE SKY SHOW

A planetary double-header makes September a rich month for solar system afficionados.

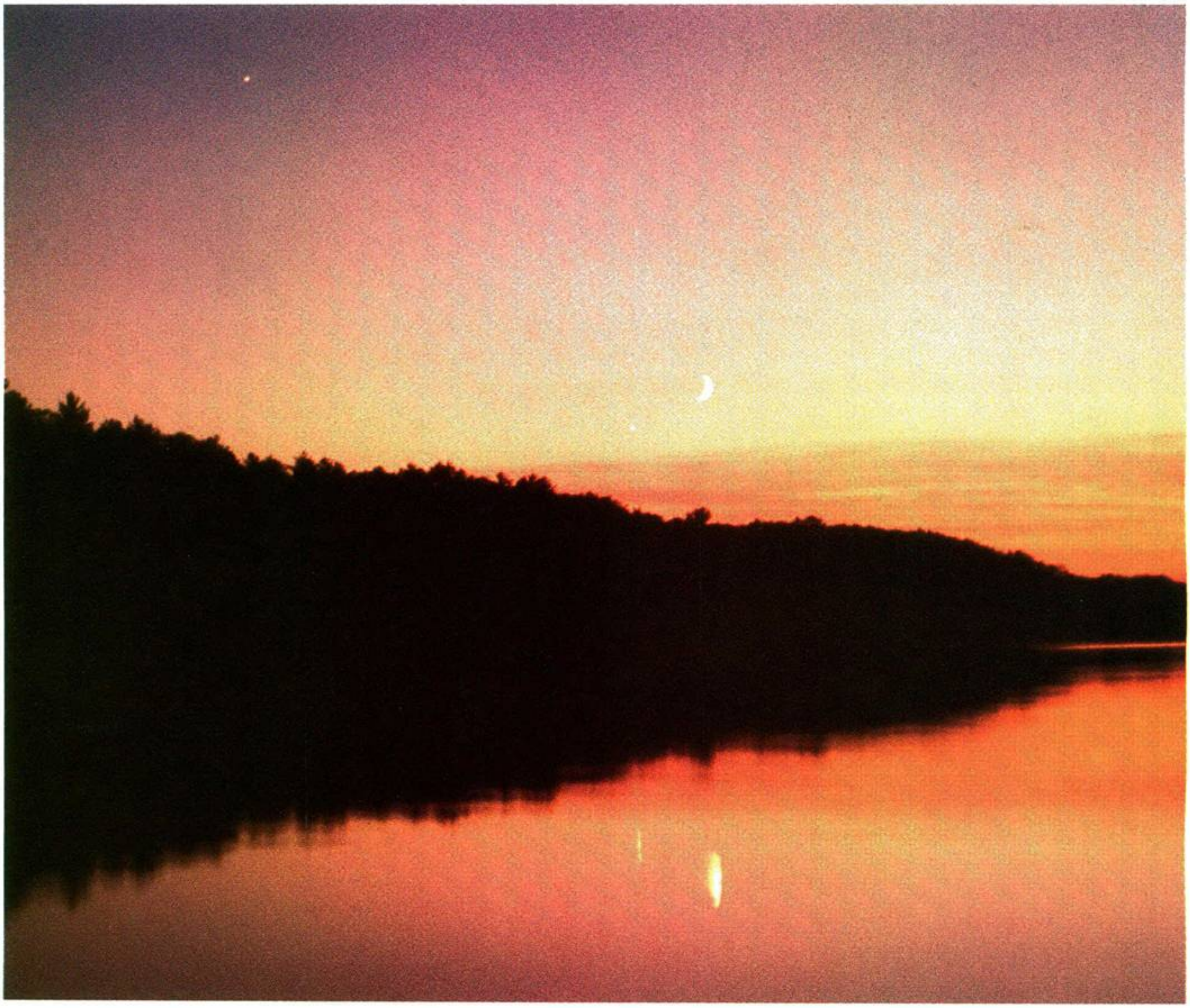
by Martin Ratcliffe and Alister Ling

▶ The evening and morning skies host a number of planets this month. Jupiter is at its best and is visible all night, while Mercury and Venus put on a great show in the morning sky as they dart around Regulus in the constellation Leo the Lion. Mars joins the morning action, while Saturn fills in the middle of the night. The three outer planets, Uranus, Neptune, and Pluto, provide a prequel to the night's main events and remain visible for a few hours after sunset. So if you can meet the challenge of seeing Pluto, then all eight planets are visible in one night.

Our planetary trek begins with **Pluto**. Until February 1999, it is closer to the sun than Neptune. Even with this favorable position, finding Pluto is always a task. The planet barely achieves a brightness greater than magnitude 14 and sets before midnight. This makes finding Pluto difficult and requires a very dark sky. Wait until a few days after the September 6 full moon then begin your search near Zeta (ζ) Ophiuchi. It's a difficult planet to detect, but the chance to see all the planets in one night is rare. Make the effort if you have at least an 8-inch scope.

Uranus and **Neptune** are binocular targets, with Uranus the easier object shining at magnitude 5.9. Neptune, at magnitude 7.9, is currently lying on the Sagittarius/Capricornus

The moon, Venus, and Jupiter shine like beacons through twilight colors. This month look for Jupiter rising in the east as the sun sets, while Venus can be found in the east before sunrise.



Andy Manning

3 The moon passes 2° north of Neptune, 6 a.m. EDT
The moon passes 3° north of Uranus, 11 p.m. EDT

6 Venus passes 0.8° north of Regulus, 6 a.m. EDT
Full moon is at 7:21 a.m. EDT; penumbral lunar eclipse (page 74)
The moon passes 0.5° south of Jupiter, midnight EDT

7 Mercury passes 0.8° north of Regulus, 3 p.m. EDT

8 The moon is at perigee (224,548 miles from Earth), 2:00 a.m. EDT

9 The moon passes 2° south of Saturn, 2 p.m. EDT

10 Mercury passes 0.4° north of Venus, 8 p.m. EDT

12 The moon passes 0.3° north of Aldebaran, 4 a.m. EDT (page 75)
Last quarter moon is at 9:58 p.m. EDT

15 Jupiter is at opposition, 11 p.m. EDT (page 74)

16 Asteroid Pallas is at opposition, 1 a.m. EDT (page 75)

17 The moon passes 2° south of Mars, 8 a.m. EDT

18 The moon passes 0.6° south of Regulus, 7 a.m. EDT

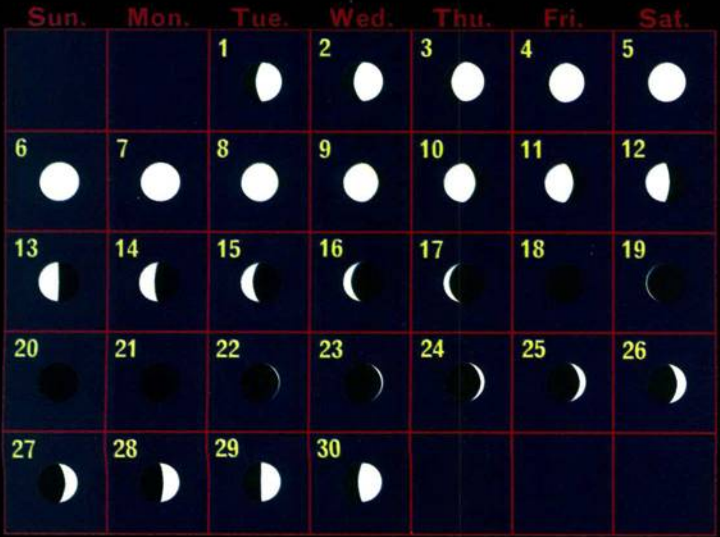
20 New moon is at 1:01 p.m. EDT

23 Autumnal equinox is at 1:37 a.m. EDT
The moon is at apogee (252,382 miles from Earth), 5:56 p.m. EDT

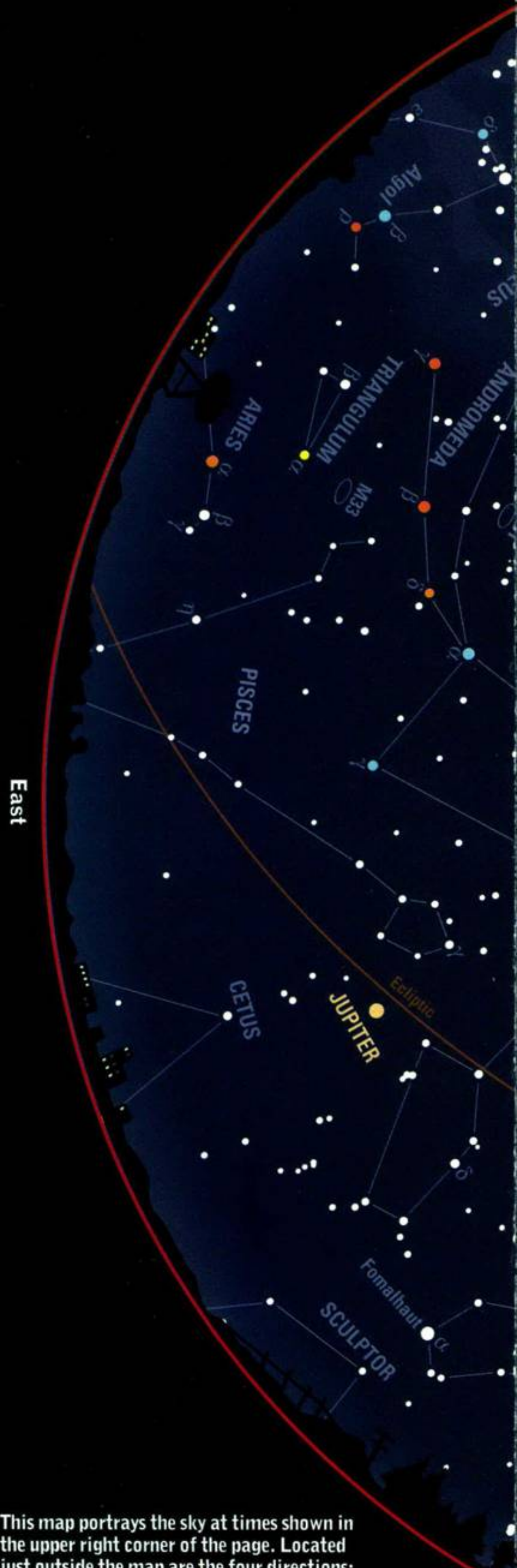
25 Mercury is in superior conjunction, 4 p.m. EDT

28 First quarter moon is at 5:11 p.m. EDT

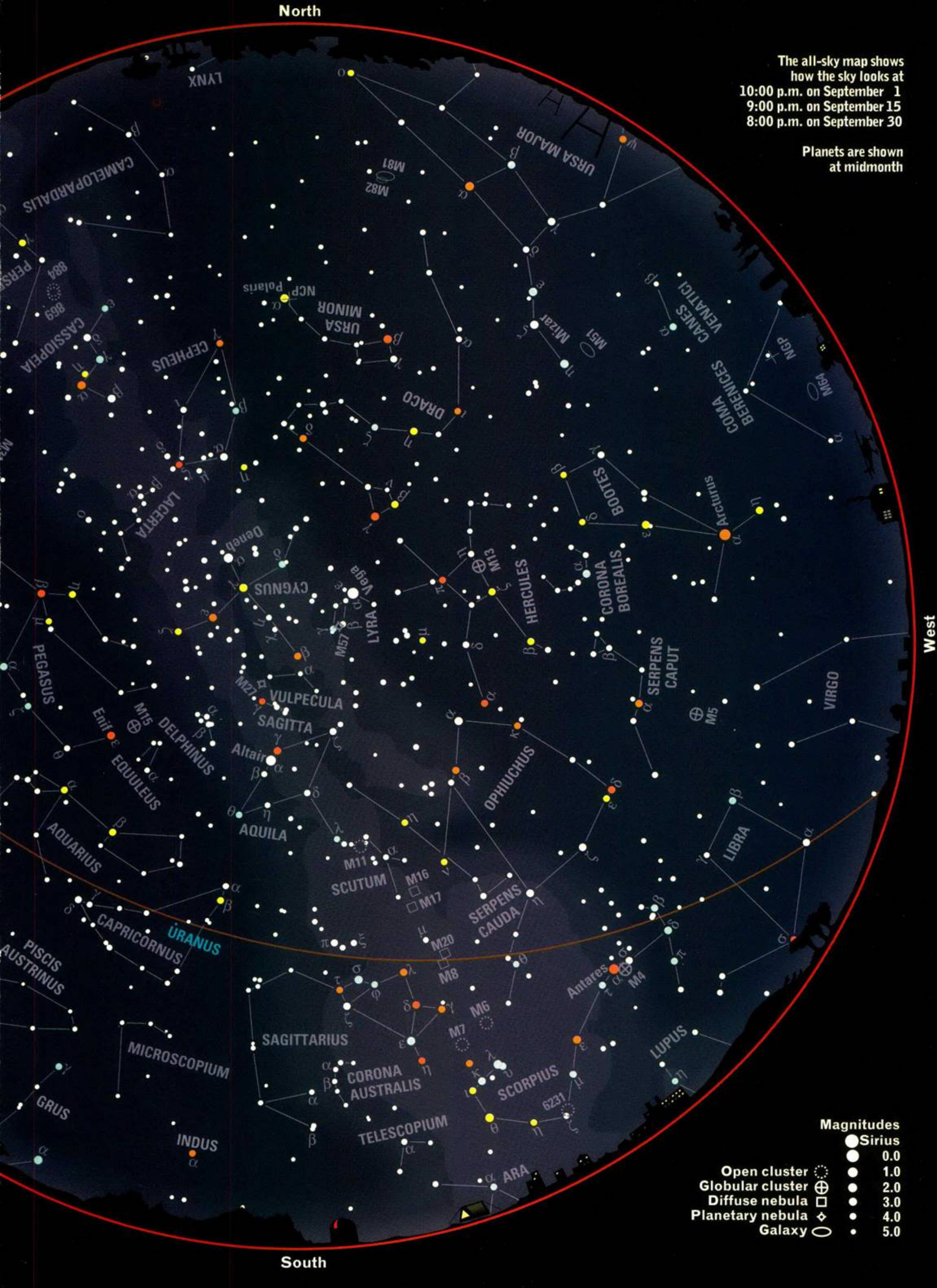
30 The moon passes 2° north of Neptune, 3 p.m. EDT



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			



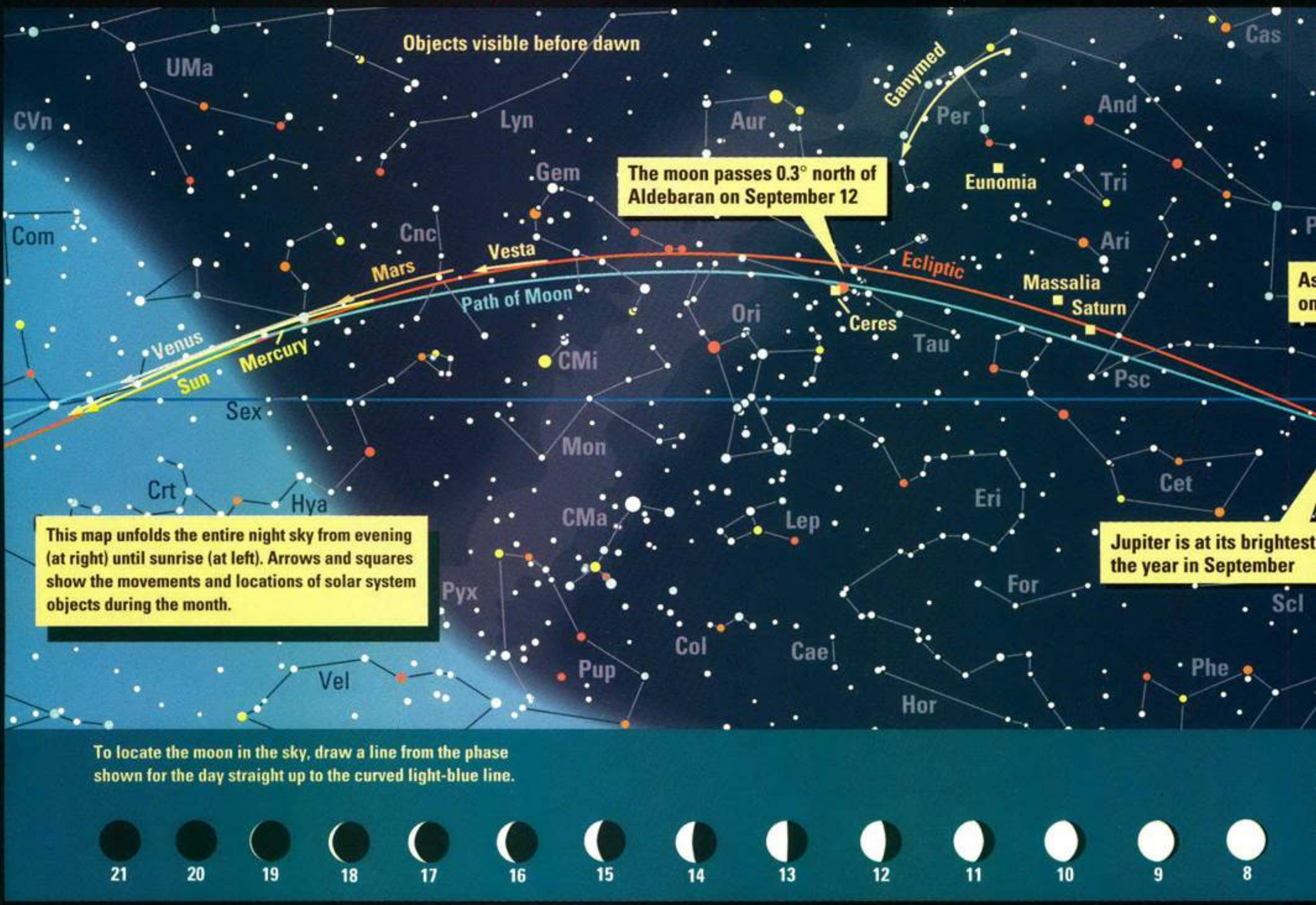
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
LYNX
CAMELOPARDALIS
PERSEUS
884
869
CASSIOPEIA
CEPHEUS
NCP Polaris
URSA MINOR
M81
M82
URSA MAJOR
Mizar
M51
CANES VENATICI
NGP
M64
COMA BERENICES
DRACO
LACERTA
Deneb
CYGNUS
Vega
LYRA
M57
M13
HERCULES
CORONA BOREALIS
BOOTES
Arcturus
PEGASUS
M27
VULPECULA
SAGITTA
Enif
M15
DELPHINUS
EQUULEUS
Altair
AQUILA
OPHIUCHUS
SERPENS CAPUT
M5
VIRGO
West
AQUARIUS
M11
SCUTUM
M16
M17
SERPENS CAUDA
LIBRA
CAPRICORNUS
URANUS
PISCIS AUSTRINUS
M20
M8
Antares
M4
M6
M7
SAGITTARIUS
MICROSCOPIUM
CORONA AUSTRALIS
SCORPIUS
6231
LUPUS
GRUS
INDUS
TELESCOPIUM
ARA
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
10:00 p.m. on September 1
9:00 p.m. on September 15
8:00 p.m. on September 30

Planets are shown
at midmonth

THE PATH OF THE PLANETS


Cas
UMa
CVn
Lyn
Aur
Ganymed
Per
And
Gem
Eunomia
Tri
Com
Cnc
Ari
P
Vesta
Mars
Ecliptic
Massalia
Path of Moon
Saturn
Ori
Ceres
Tau
Venus
Mercury
Sun
CMi
Psc
Sex
Mon
Cet
Crt
Hya
Eri
CMa
Lep
Pyx
For
Scl
Col
Cae
Pup
Phe
Vel
Hor
21
20
19
18
17
16
15
14
13
12
11
10
9
8

Objects visible before dawn

The moon passes 0.3° north of Aldebaran on September 12

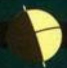
As
on

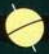
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

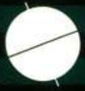
Jupiter is at its brightest
the year in September

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

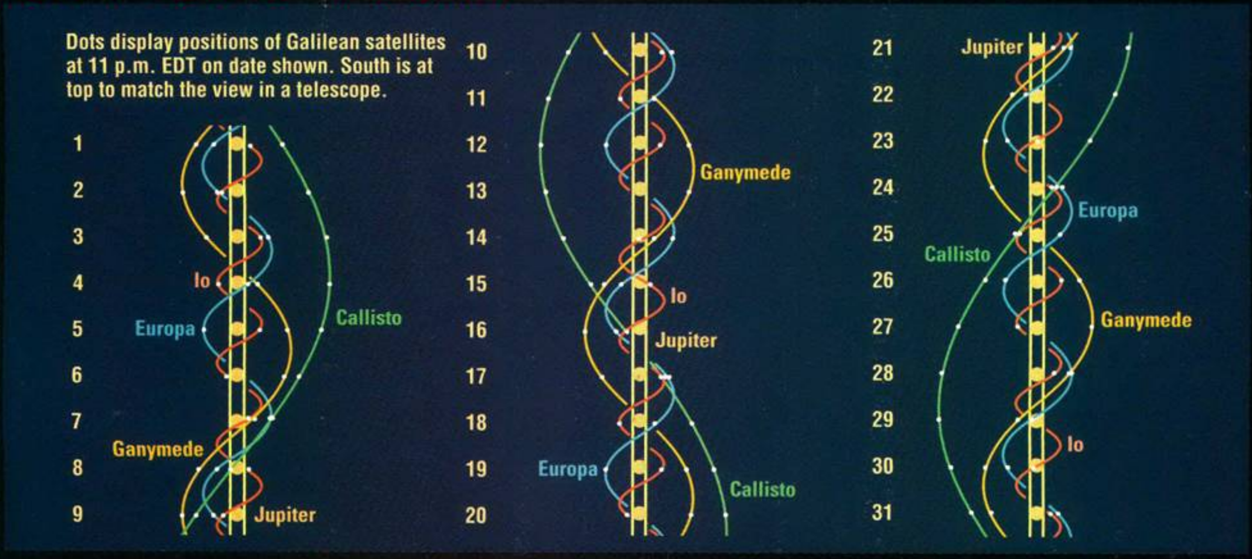
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	September 1	September 15	September 15	September 15	September 1
Magnitude	–0.3	–1.3	–3.9	1.7	–2.9
Angular Size	7.2"	5.3"	10.0"	4.0"	49.7"
Illumination	47%	93%	98%	97%	100%
Distance (AU) from Earth	0.939	1.276	1.672	2.328	3.963
Distance (AU) from Sun	0.315	0.331	0.719	1.624	4.968
Right Ascension (2000.0)	9h30.5m	10h58.0m	10h48.8m	9h15.5m	23h37.6m
Declination (2000.0)	14°40'	8°33'	9°00'	17°08'	–4°07'



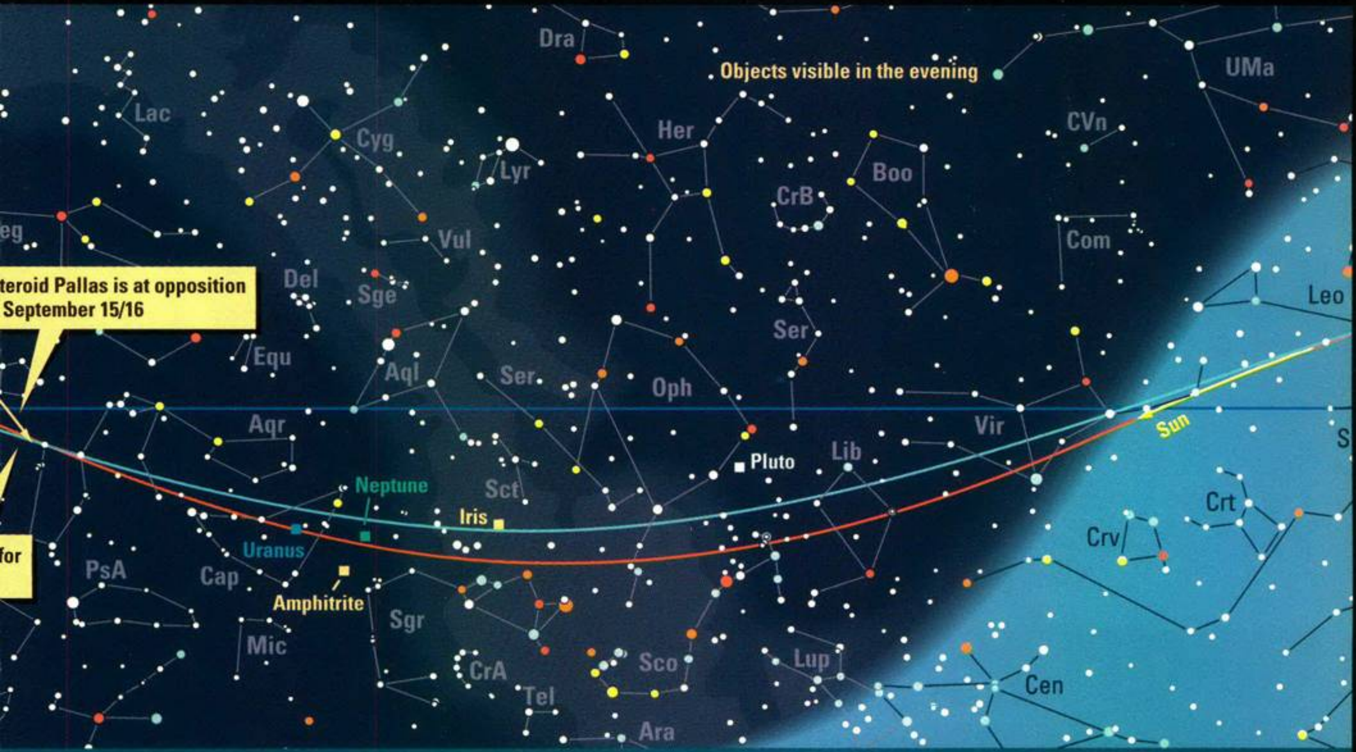




JUPITER'S MOONS

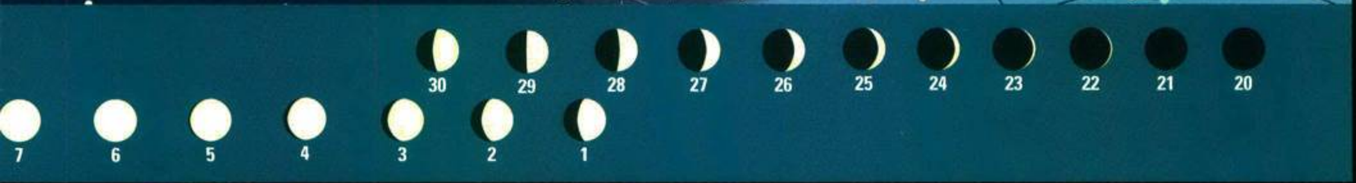


Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.


Dra
Objects visible in the evening
UMa
Lac
Cyg
Lyr
Her
CVn
Boo
CrB
eg
Vul
Com
Del
Sge
Leo
Ser
Equ
Aql
Ser
Oph
Aqr
Vir
Sun
S
Pluto
Lib
Neptune
Sct
Iris
Crt
Uranus
Crv
PsA
Cap
Amphitrite
Sgr
Mic
CrA
Sco
Lup
Tel
Cen
Ara

teroid Pallas is at opposition
September 15/16

for


30
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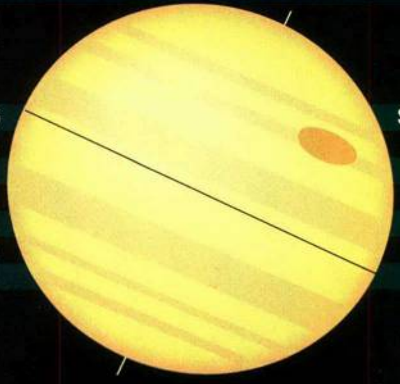
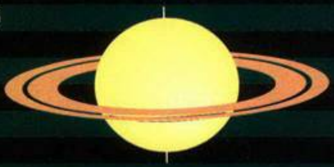
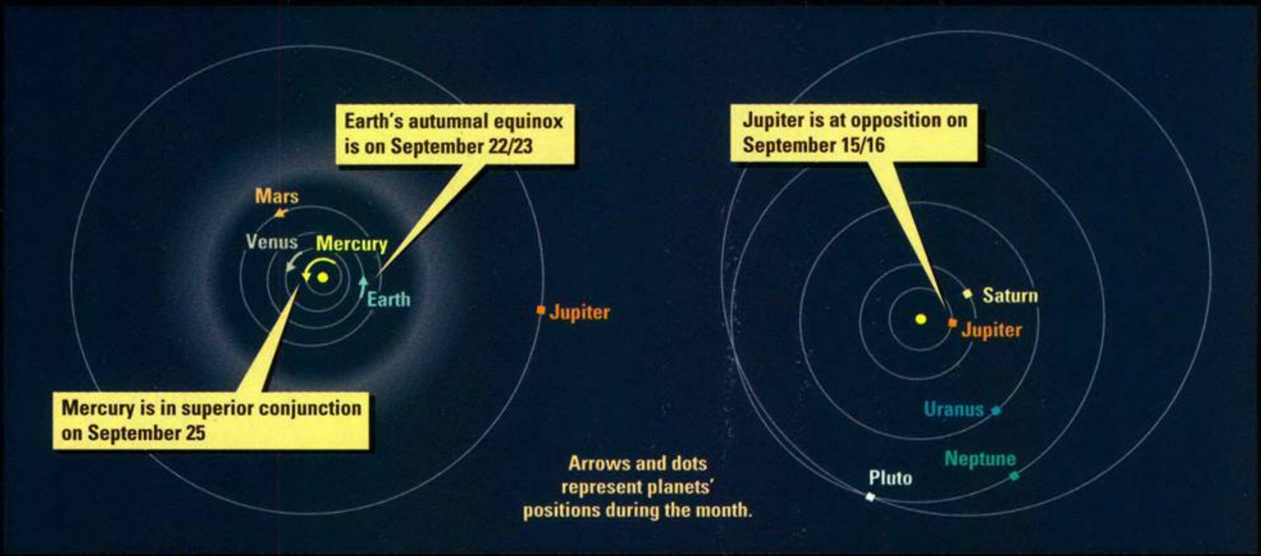




SATURN	URANUS	NEPTUNE	PLUTO
September 15	September 15	September 15	September 15
0.0	5.7	7.9	13.8
19.5"	3.7"	2.3"	0.1"
100%	100%	100%	100%
8.514	19.123	29.513	30.356
9.297	19.874	30.137	30.093
2h06.4m	20h47.6m	20h06.7m	16h23.0m
9°56'	–18°35'	–19°55'	–9°39'

THE PLANETS IN THEIR ORBITS


Mars
Venus
Mercury
Earth
Jupiter
Saturn
Jupiter
Uranus
Neptune
Pluto

Earth's autumnal equinox is on September 22/23

Mercury is in superior conjunction on September 25

Jupiter is at opposition on September 15/16

Arrows and dots represent planets' positions during the month.

border. This blue-green orb pales in contrast to the waxing moon's brilliance when it passes 2.4° north of the planet on September 3. The following night, a nearly full moon passes a similar distance north of Uranus, which is casually moving through Capricornus. Both planets remain above the horizon until after midnight, but it's best to catch them early while they are at a reasonable altitude.

While these three represent the toughest planetary challenge, the easiest is **Jupiter**. The solar system's largest planet dominates the entire night sky. It's visible 30 minutes after sunset as it rises almost due east. Even casual observers can see that Jupiter is opposite the sun this month. Opposition occurs on September 16, when the planet is visible all night. Other than the moon in early September, Jupiter is the brightest object in the evening sky. It peaks at magnitude –2.9 among the stars of Aquarius the Water Bearer.

You can identify Jupiter easily on September 6. The full moon draws attention to the brilliant planet by moving less than 1° south of it. Telescopically, Jupiter is a treasure full of gems. Its large apparent size of 49.7" allows delicate detail in the jovian cloud deck to be seen by the attentive observer. Even a quick glance through an eyepiece will reveal the two broad equatorial belts that straddle the planet's equator. We can also watch the dance of the four major satellites of Jupiter — Io, Europa, Ganymede, and Callisto — as they wander back and forth around the planet like well-trained fireflies. Occasionally these satellites pass behind or in front of the planet's disk, occulting or transiting it. Io, the most fleeting of the four satellites, undergoes such events daily. Before a satellite is occulted by Jupiter, we sometimes can see it slip into the shadow of the giant planet. These shadow eclipse events can be observed during the months on either side of opposition.

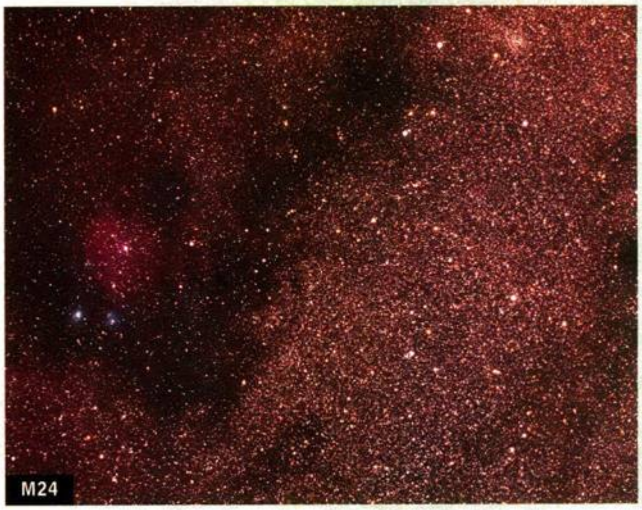
In the early morning of September 6, the moon travels through the outer edge of

FIRST VIEW: Treasures of the Small Sagittarius Star Cloud

Galaxy observers dream of seeing incredible detail in edge-on galaxies. Sometimes they forget that the best edge-on is right in front of them — the Milky Way, which is viewed from within, rather than from the outside. A few degrees away from galactic center, above the spout of the Teapot, lies the naked-eye M24, appearing like a puff of steam in the sky. M24 is a piece of the galaxy that appears to be detached by the surrounding dark nebulae.

Comet hunter Charles Messier himself noted in his observation of June 20, 1764, that this object is a "large 1.5° nebulosity in which there are several stars of different magnitudes: The light which is spread throughout this cluster is divided into several parts." What is missing from his notes are the passionate descriptions of amateurs who revel in the object's wonderful tangles of star clumps and dark nebulosity.

The most frequently recorded detail in M24 is the small star cluster NGC 6603 (top right corner of photo at right), discovered by the 19th-century observer John Herschel. He expressed surprise that Messier did not see the cluster, and somehow his words were later shaped into the myth that NGC 6603 was what Messier saw. A modern day 4-inch scope at 64x easily picks up an unresolved clump here, though Messier's inferior optics could not.


M24

Jerry Lodriguss

Sagittarius Region

Luke Dodd

By far the most spectacular part of the star cloud is the invisible. On one side, the Great Rift of the Milky Way courses through the field. The western flank is adorned by large splotches of black ink, as if a celestial painter flicked a brush onto the sky's canvas. Dark gas and thick obscuring dust abound in this region, all preventing the rich galactic star light from shining through. These are among the sky's easiest Barnard dark nebulae.

Barnard 92, 93, and 304 are the darkest of the lot. In less than ideal conditions you might just see them as the places where the stars disappear. But with a really dark sky, the surrounding area is incredibly peppered with tiny faint stars that make the dark nebulae appear wondrously black.

Earth's shadow, causing a penumbral eclipse. Although the penumbra is not as deep as the umbra, the moon does dip 84 percent of its disk into this outer shadow, making the northern edge of the moon noticeably darker at mid-eclipse. The eclipse peaks at 7:10 a.m. EDT. Observers on the east coast will be able to see the early stages of the eclipse in the bright twilight before sunrise. Those in the central time zone and farther west will see the eclipse in progressively darker skies.

On this same eclipse morning, **Mercury** and **Venus** rise with Regulus. Venus lies a mere 0.8° from Regulus, the 1st-magnitude star marking Leo the Lion's heart. This conjunction is followed on September 7 by Mercury only 1° from the star. On this date, Mercury, Venus, and Regulus form a neat little triangle in the morning sky. Mercury's magnitude of –1 outshines Regulus at magnitude 1.4, but Venus tops them both at magnitude –3.9. Four mornings later, on September 11, Mercury and Venus are only 0.4° apart. Both planets are falling into the sun's glare quite rapidly, but the brilliance of Venus will act as a guide to finding Mercury for several days. This is the year's finest morning apparition of Mercury, with its peak on September 1, and the events following that date make it a fine target for more than a week.

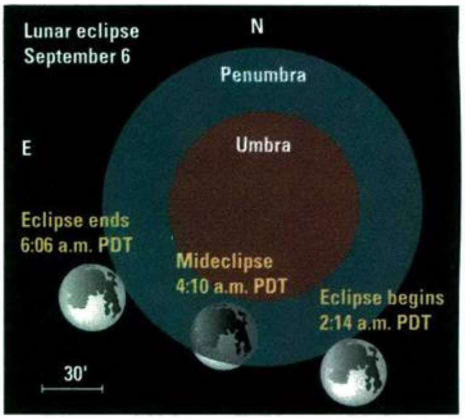
September 1 also finds **Mars** in the morning sky. Located deep in the heart of the Beehive Cluster (M44), Mars provides binocular viewers with its brilliant orange globe amidst dim yellow stars — an attractive sight for the cool morning hours. It remains too

Lunar Shadowland

Observers west of a line from Louisiana to Manitoba will be able to note a somewhat dusky veil cover over the moon early on the morning of September 6, as Earth's outer shadow (the penumbra) shrouds the moon. Penumbral eclipses are not as exciting as partial ones. From the point of view of the moon, the sun is partially eclipsed and no part of the moon is in total darkness. The dusky glow is most often seen as a pale yellow-brown shading, which in this instance will be on the top side of the moon.

Technically, the start of the penumbral eclipse is at 3:14 MDT (4:14 CDT, 2:14 PDT), but it is unlikely that any shading will be seen until at least an hour later. The deepest shading will occur at central eclipse at 5:10 MDT.

The most interesting place to watch the eclipse will be from areas that see sunrise just after the mid-point. Just before sunrise, those areas will see Earth's shadow slice through the atmosphere in the west, resulting in a deep blue-gray shadow band that will hug the horizon with a pink-purple sunlit layer above it. You will be able to visualize Earth's shadow extending outward to the moon. This will best be seen along a line from Lake Superior to Florida and could be a nice picture, though the veil itself may not be visible.



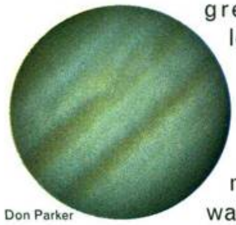
All illustrations by *Astronomy*: Terri Field

Jove Rules

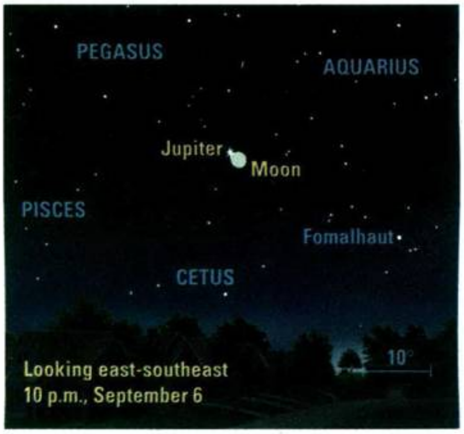
With Jupiter opposite the sun this month, it rises at sunset and sets at sunrise. This means that it is well placed for both public and private observing sessions.

If it's not already in the public eye, Jupiter will be on the night of September 6–7. On that night, the nearly full moon slides below the planet. As you view Jupiter, take time to think about its relative size. From Earth, the moon is 50 times bigger than Jupiter. Yet in reality it is barely bigger than Jupiter's moon Europa, the smallest of the Galilean satellites. In most telescopes, Europa appears to be no more than a dot. Currently, Europa is about 1" across and observers will need both great seeing and at least an 8-inch scope to see any appreciable disk.

To get the most out of Jupiter, you must spend time watching it. This is the only way to catch those fleeting moments of significantly better seeing. These moments come when the view through Earth's atmosphere is between turbulent pockets of air. You'll want to wait until the planet is at least 15° above the horizon for reasonable detail. To best see the red spot, use a blue filter to darken the red spot relative to the lighter colored clouds.



Don Parker



Looking east-southeast
10 p.m., September 6

far from Earth to see any appreciable detail, yet its wanderings among the background stars can provide endless fascination.

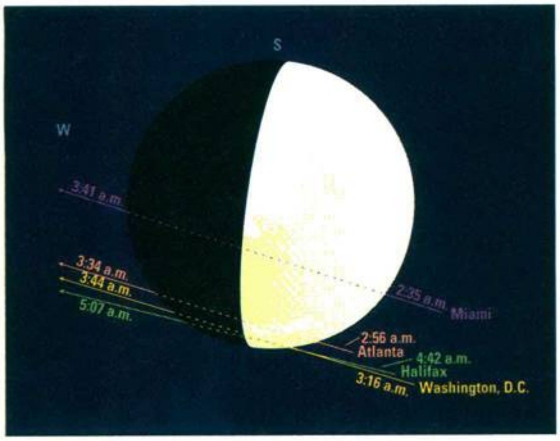
The remaining planet in the quest to see all eight in one night is **Saturn**. It's an easy target shining brightly among the stars of Cetus the Whale and Pisces the Fish. It rises less than two hours after Jupiter and is best viewed in the late evening or early morning hours. The majestic ringed planet continues to brighten as it approaches its October 6 opposition, when it will rival the star Vega with its brilliance.

The major planets are not the only solar system objects showing off this month. Asteroids share some of the limelight as well. Pallas, asteroid number 2, is also at opposition and lies a mere 3° north of Jupiter on September 7. It's a binocular object at magnitude 8.2 and is wandering near the "Circlet" asterism in southern Pisces. Slightly brighter Ceres wanders within 40' of the brighter star Aldebaran in Taurus the Bull on September 4. Asteroid 5 Astraea is also near the Hyades in Taurus, passing 26' south of Gamma (γ) Tauri on September 7.

Evening views of the night sky in September are full of splendor. The full moon in the first week soon leaves the evening sky as mid-September approaches. The darker, moonless sky offers the finest views of the rich Milky Way that runs from Cygnus overhead to Sagittarius near the southwestern horizon. The transition from summer to winter is underway, marked by the autumnal equinox on September 23.

The stars also mark the transition of seasons. The

Luna Scores Another Bull's Eye



The whole world has had several opportunities in the last two years to watch the moon shut off the light from ruddy Aldebaran. For this month's event in the continuing series, eastern North America has the only seat with a view of the stage.

Aldebaran is a red giant — its disk is large enough to allow the moon's edge to noticeably take a fraction of a second to hide the star completely. Other stars are so far away or so small that their light gets cut off instantly by the moon's limb. This means that the star fades instead of blinking off.

By far the most exciting places to be on the night of September 11–12 are those along a line from central Texas through Kentucky and right along the Maine coastline. The event takes place around 5 a.m. EDT. Along this line, the moon's limb grazes Aldebaran, alternately hiding it behind a peak, then allowing it to shine through a valley.

Grazes are pretty spectacular to begin with, but with Aldebaran gradually appearing and disappearing several times in a row, the event becomes a rare highlight in one's observing life. To learn more, visit IOTA's website at: http://www.sky.net/~robinson/iotandx.htm.

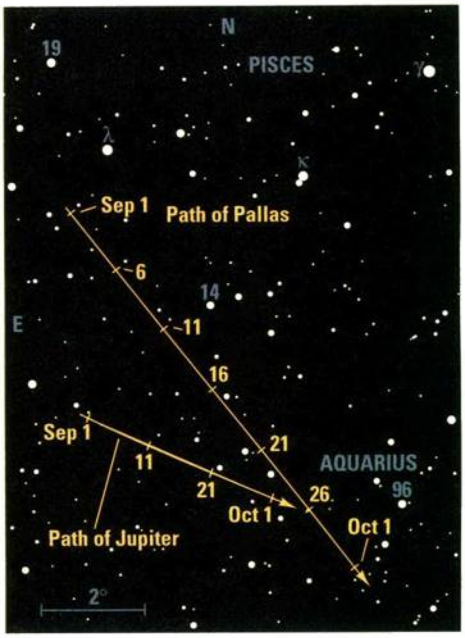
Pallas Floats Near Jupiter

This month asteroid 2 Pallas is easy to spot — it's in the same binocular field as Jupiter. You'll still need a telescope or dark sky to find the asteroid, since at its brightest it only reaches magnitude 8.2.

Why is the second asteroid to be discovered so faint? Because it is almost at the most distant part of its orbit — aphelion. In a year and a half Pallas will peak in brightness near 7th magnitude. The asteroid is 400 miles across, making it the second largest of the main belt asteroids.

Pallas is surprisingly near the ecliptic. Most asteroids lie close to this plane of the solar system, but Pallas has one of the highest inclinations away from the ecliptic, 35°, so it tends to encounter a wider variety of deep-sky objects on its travels around the sun. Unfortunately, that's not the case this month, but keep a look out for close passings in the future.

While you are in the area, have a peek at 19 Piscium in the Circlet just to the north. It is a beautiful ruddy-orange carbon star.



OBSERVER'S CHALLENGE: Naked-Eye Globulars

It's always fun to play the challenge of "How far can you see?"— for most observers this is 2.2 million light-years to the Andromeda Galaxy (M31), or even farther to M33 in Triangulum. This game, like any sport, can be extended to different categories. The Hercules Cluster (M13) is relatively easy for Northern Hemisphere observers, while 47 Tucanae and Omega Centauri are hardly even challenging for southerners. But how many globulars can you see with the unaided eye?

Globular clusters are large conglomerations of millions of stars. Though they are considered part of our galaxy, the Milky Way, they are outside of the galaxy's disk. Globular clusters form a halo around the central sphere of our galaxy. If we could fly outside of and away from the Milky Way, globular clusters would look like individual swarms of bees hovering around the central bulge of our spiral home.

Our first challenge is M22. It has a total visual magnitude of 5.1 — brighter than M13's magnitude 5.7. One problem with M22 comes from its proximity to the horizon for observers who live north of latitude 45°. Those living at that latitude will have difficulty spotting the cluster through the often hazy lower atmosphere. If that is a problem for you, try magnificent M4 hiding in the glare of Antares.

One of the things to remember in this challenge is that globulars are not like stars. Their light is spread out. That means a 6th-magnitude fuzzball is actually a bit tougher than its apparent magnitude indicates. Naturally, you'll need a dark sky — don't even use a red light on charts because it will harm your dark adaptation.

Our next target, M5, is large enough to be seen as a fuzzy spot. It can be a challenge to separate the cluster from nearby 5 Serpentis. The star is magnitude 5, and the globular is 5.7. Good luck.

M3 is a tough magnitude 5.9. Use the stars 3 and 9 Bootis as your guideposts to start your hop, and remember to use averted vision. If you look to the side of the globular's location you may have a better chance of spotting it. Also shade your eyes from earthbound light sources.

It's an easy hop to magnitude 6.0 M15 from the bright stars of Pegasus. The trick here is a 6.1-magnitude star just to the east. It took a few nights before I got a nice enough sky to convince myself I saw two objects.

M92 at magnitude 6.4 is thus far the faintest on the list. I found it easier to spot than M15 because there are no nearby faint stars and it is placed high in a dark sky. Once you know where to look in northern Hercules, you can use M92 as a benchmark of the sky's darkness.

Has anybody seen M10? In order to spot this pale magnitude 6.6 glob, you might require dark southern skies, like those at the Texas Star Party.

Southern Hemisphere observers should also attempt NGC 6752, NGC 6397, NGC 2808, NGC 6541, and NGC 362. Let *Astronomy* know how you fared.

M22

John Chumak

M5

Mace Hooley

M4

Lee C. Coombs

red eye of Taurus, 1st-magnitude Aldebaran, rises in the east marking the approach of winter, while the last glimmer of brilliant orange Arcturus, in Bootes the Herdsman, sets in the west. These stars of springtime will return next year. The Big Dipper, the great asterism within Ursa Major the Great Bear, completes its cycle around the pole once more and prepares to settle near the northern horizon ready for its winter hibernation. High above our heads, the bright gems of the summer sky — Cygnus, Lyra, and Aquila — linger overhead a while longer but will eventually make way for the autumnal sky by 10 p.m.

The month closes with the Great Square of Pegasus standing proudly high in the south by late evening. The constellation leads the procession of the dim but interesting fall stars. The Greek mythology surrounding the Winged Horse is quite interesting. After his birth, Pegasus flew to Mount Helicon in Boeotia, the home of the Muses. The place where his hoof struck the ground became a water spring. It is appropriate that to the south of Pegasus is Aquarius the Water Bearer, Pisces the Fish, and Cetus the Whale — all aquatic constellations. The diminutive Delphinus the Dolphin — a neat little summer constellation just northeast of Altair in Aquila — appears to be leading Pegasus to the river of starlight that divides the sky, the Milky Way.

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

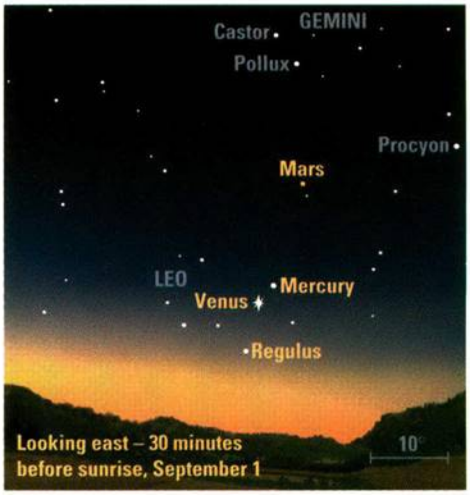
Crowded Morning Skies

The first days of September are good times to wake early to watch the morning solar system action. Mars, Mercury, Venus, Regulus, and the moon each take leading roles along the ecliptic, which is now more steeply inclined to the horizon than it was during the summer months.

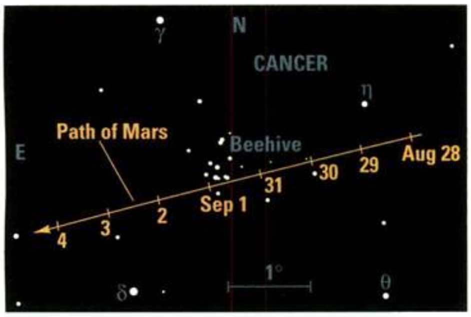
Mars acts as queen bee on September 1 — its rusty magnitude 1.6 orb dominates M44, the Beehive Cluster.

Venus will gradually disappear into the twilight glow, but first it dances with Regulus and Mercury. The innermost planet is ending its best morning display of the year. Magnitude –0.3 Mercury starts 2° to the upper right of *brilliant* Venus. Regulus seems to climb up away from the sun to greet them between September 6 and 8 — in reality it is the planets and the sun sinking down past Regulus as Earth orbits the sun. Mercury then slides a moon's width past Venus on September 10–11 and disappears into the twilight glow a few days later.

The waning crescent moon scoots past Mars on September 17 and Regulus on the 18th. With only 32 hours to go before new moon, the slender crescent catches Venus coming within 3° on the morning of September 19.



Looking east – 30 minutes before sunrise, September 1



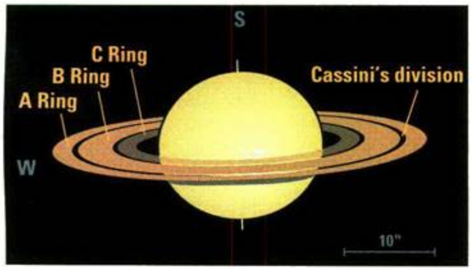
Saturn Satiates

Despite Jupiter's controlling interest in the early evening sky, scopes will be turned quickly to the beauty of Saturn and its rings. As the planet climbs off the horizon, the view will be better.

The south pole of Saturn is tilted 16° toward Earth, still gradually opening over the next few years. With this sort of tilt, Cassini's division and the more difficult Encke's division are easier to notice. Use the rings to help you visualize the plane of the satellite's orbits. Between inverted telescopic images and Saturn's south pole facing us, it's easy to get confused as to which way is up and what way the moons are going. It's as if we are below Saturn, looking up it at.

Check out the shadow of the ball on the rings. It will steadily shrink until it disappears in late October. The shadow is primarily responsible for helping us see Saturn in "3-D" so vividly. On nights of good seeing, increase the power and watch the moons gradually shift their places.

Jack Newton



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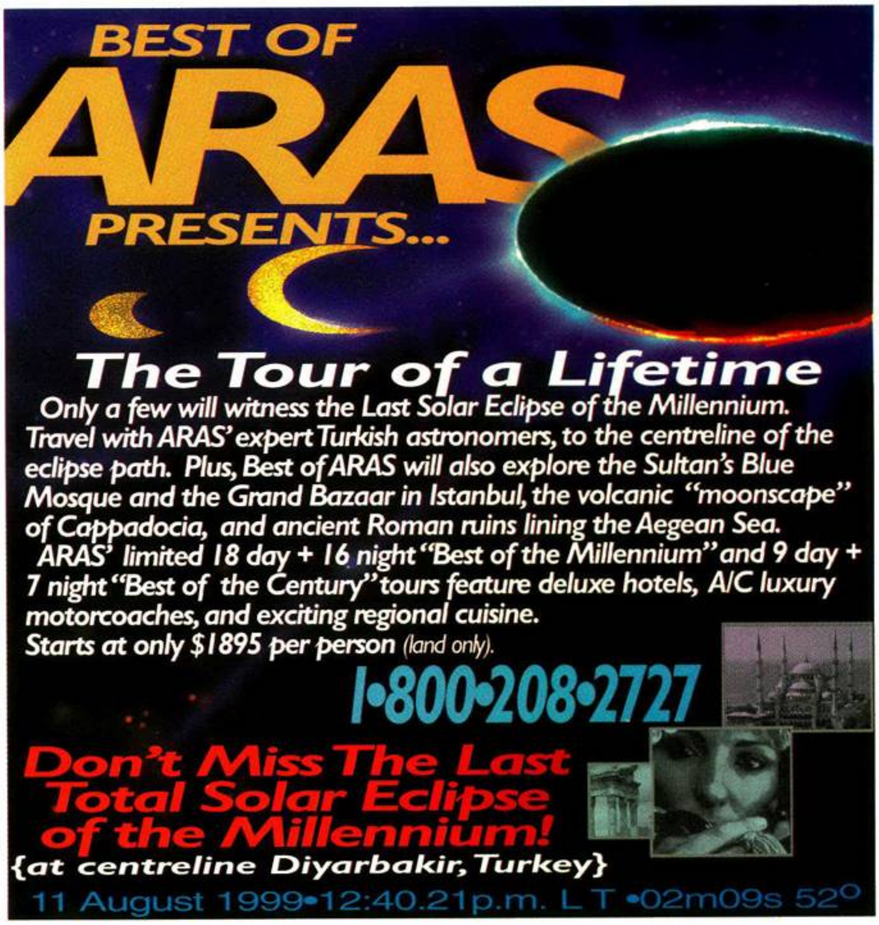

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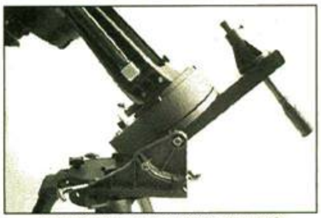

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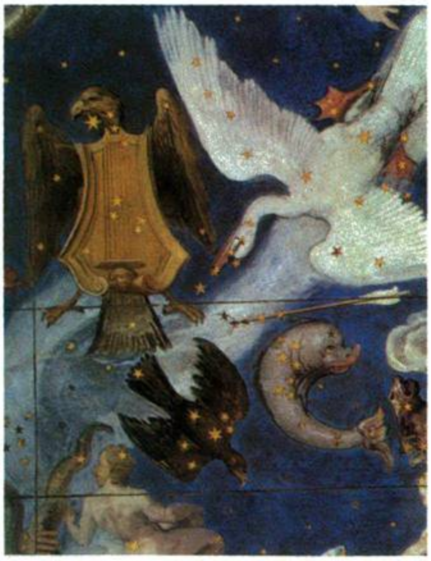
CELESTIAL PORTRAITS

CYGNUS & LYRA



Between the feathers of the Swan and the strings of the Harp, the abundant field of the northern Milky Way awaits.

by Tom Polakis

Artwork at left originally published in *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

CYGNUS THE SWAN AND Lyra the Harp are two of the summer sky's most recognizable constellations. Lyra appears to observers as a parallelogram of stars hanging to the south of its brightest star, magnitude 0 Vega. The fifth brightest star in the sky, Vega is only 26 light-years away — it's practically in our neighborhood. Northeast of Vega is Epsilon (ε) Lyrae — a pair of stars separated by 3.4'. Lyra's proximity to the Milky Way's plane makes it a constellation swimming with stars.

East of Lyra you'll find Cygnus. The focal point of the constellation is 1.3 magnitude Deneb. Although it is 1,600 light-years away, Deneb is 70,000 times more luminous than the sun and rivals the apparent brightness of closer stars. Cygnus the Swan looks like its namesake. The long neck of the Swan extends along our galaxy's plane to the beautiful double star Alberio (Beta [β] Cygni), while the wings are perpendicular to the galaxy's diffuse glow.

Epsilon (ε) Lyrae, also called the Double Double, is a wide optical pair that splits into two binary systems through the telescope. Neither pair is particularly difficult to split, so the most pleasing views may be enjoyed in small refractors. Epsilon^1 is the northern pair whose components are separated by 2.6". The system is revolving slowly with a 1,165-year period. To the south is Epsilon^2. Its component stars are currently separated by 2.3" and orbiting with half the period of Epsilon^1. Their orientations are nearly at a right angle to each other. Use a magnification above 200x to split both pairs. If the stars appear to be boiling and churning, try again on another night when the air is more stable.

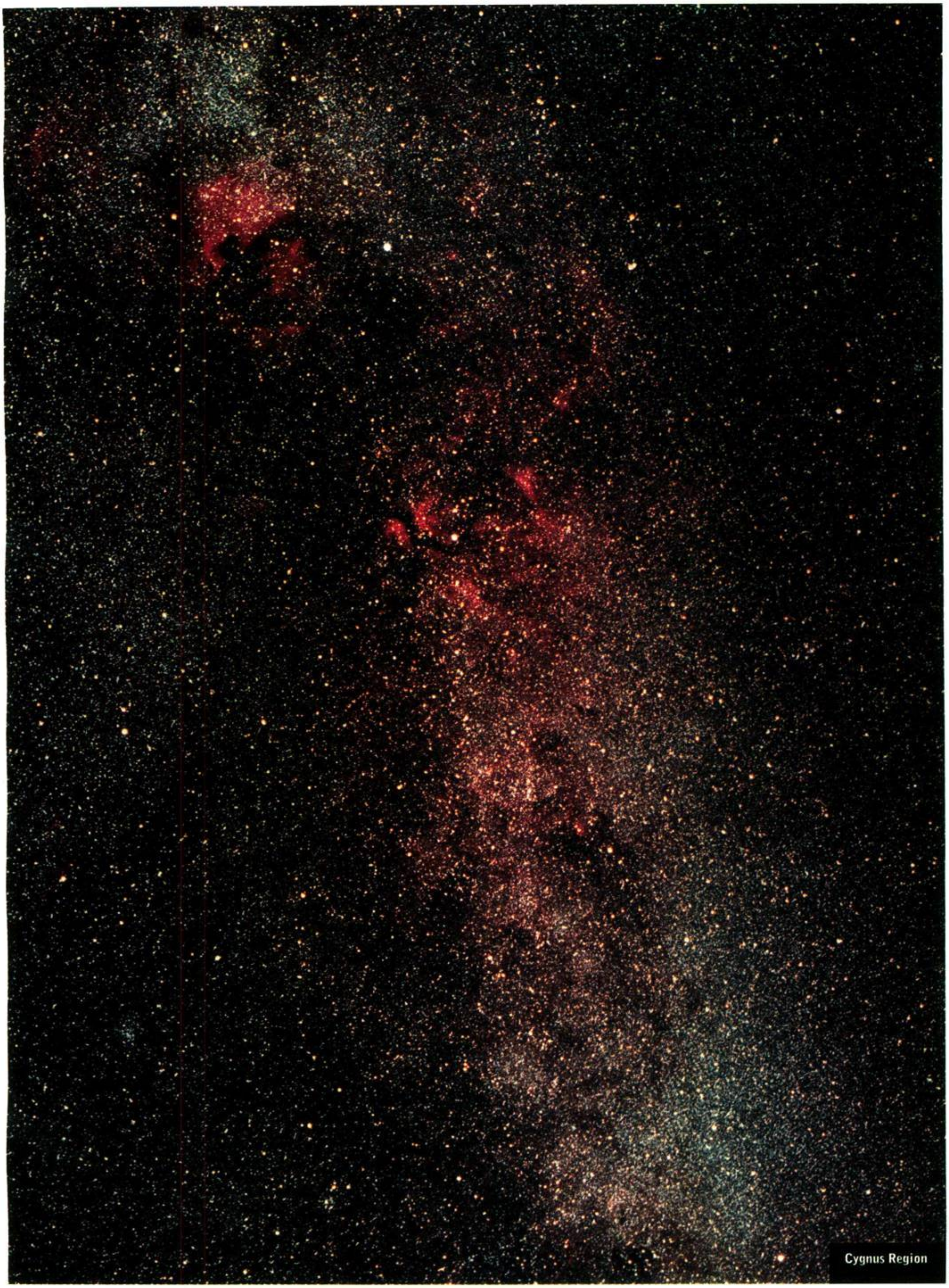
A line from Vega through Epsilon Lyrae points to our next target, **NGC 6745**. This galaxy is both faint and small, but its appearance is peculiar enough to warrant a look. It shows no surrounding halo; instead, it appears as a lenticular disk oriented north-south with a flat western edge. A 14th-magnitude star punctuates the galaxy's northern end. NGC 6745 is actually a system of three interacting galaxies. It requires a high-resolution image of the trio to make any sense of the odd form seen through the eyepiece.

The **Ring Nebula** (M57, NGC 6720) is among the most observed objects in the heavens. Even a department store telescope under urban skies will show the nebula's doughnut shape. At a dark location with a 6-inch telescope, the Ring Nebula appears as an oval disk elongated roughly east-west with a dark circular center. A 12-inch telescope shows the disk to be fainter at the ends. With a 20-inch scope, observers can hope to see brightness variations along the surface and a central hole that glows noticeably brighter than the surrounding sky. Although visual observers can hardly expect to see it, deep CCD images show a surrounding shell three times the diameter of the commonly observed disk.

The visibility of the Ring's central star has been discussed for many years. Some observers claim to spot it easily using a 6-inch scope, while others are defeated with a 13-inch. If you decide to try it, remember that you are looking for a 15th-magnitude star against a background that is not completely dark. Lowell Observatory astronomer Brian Skiff has written about photometric measurements of stars in the vicinity of M57. You can find the article at http://www.psiaz.com/polakis/m57/m57.html.

If you have the incentive to look for M57's central star, then you may want to take a shot at the extremely faint galaxy **IC 1296** only 4' to the northwest. In an 18-inch telescope at 300x, IC 1296 appears to be a faint smudge.

On the eastern edge of Lyra near the Cygnus border lies the faint open cluster **NGC 6791**. It is one of the oldest open clusters and is estimated to be 9 billion years old — rivaling the youngest globulars. The average open cluster has an age near 100 million years. Telescopically, something about NGC 6791 doesn't look quite right. The overall glow of its stars shows up well in a 6-inch, but at higher magnifications only clumps of its stars



Cygnus Region

Carl W. Weber

The Pelican Nebula

Tony and Daphne Hallas

begin to show. The cluster comes into its own right with a large aperture scope that will bring out its spectacularly rich display of 16th- and 17th-magnitude stars. A 16-inch may show as many as a hundred members evenly scattered over an area 10' across, giving the open cluster the appearance of a very loosely concentrated globular.

Lyra's only globular cluster is **M56** (NGC 6779). M56 is easily located along a line from Gamma (γ) Lyrae to Beta (β) Cygni. It is catalogued as a bright, 8th-magnitude cluster, but its stars are faint and may be difficult to resolve in telescopes smaller than 6 inches. Larger apertures bring out many faint stars scattered across 4'. It has a broadly concentrated center, and the surrounding field is uniformly rich with Milky Way stars.

Just over a degree to the west of M56 lies the strange planetary nebula **NGC 6765**. This cloud is faint and roughly 1' by 0.5' across. It has a bright center and a 14th-magnitude star on the northeast end. In a 13-inch scope, NGC 6765 appears more like an edge-on galaxy than a planetary nebula.

Albireo (Beta [β] Cygni) is an urban-star-party favorite. The rich orange and blue components of this double star are in stark contrast to one another making this one of the most beautiful pairs in the sky. Medium-power binoculars will split the two stars, which are separated by 34". Beta^1 and Beta^2 Cygni have shown no sign of orbital motion in more than one hundred years of observations. Because the two stars are so massive with nearly identical distances, they are almost certainly gravitationally bound. Beta^1 Cygni is itself a very tight binary with a 5.5-magnitude companion separated by only 0.4".

M29

Jack Newton

Forming a triangle with 4th-magnitude stars 39 and 41 Cygni is **NGC 6894**, a planetary nebula that exhibits ring structure in larger telescopes. Telescopes smaller than 8 inches show only a hazy disk about 40" across with a diffuse edge. Through a 13-inch scope, the dark 20" center appears. Still larger telescopes reveal a faint star northwest of the ring's center. Recent estimates place the planetary at 3,400 light-years away.

The introduction of nebula filters into the hobby nearly two decades ago brought the **Veil Nebula** (NGC 6960, NGC 6992–5) into the mainstream as a visual object. The remnant of a 30,000 year old supernova explosion and estimated to be 2,500 light-years away, this tenuous cloud covers an area some 2.7° by 3.8° wide. The small refractor wins for providing the most pleasing single view of the Veil. At 20x, both arcs are visible in one field, giving the correct impression of an expanding shell. Through an 8-inch scope with a narrow-band filter, such as an Oxygen III filter, web-like structure fills the field.

There are two main sections to the Veil. NGC 6960 strings its way past 4th-magnitude 52 Cygni. It tapers to a sharp point at the north end of a strip more than a degree long. As it broadens to the south, a dissecting lane begins to show up. Panning 2° to the east brings in the brighter swath of nebulosity, NGC 6992–5, the second component. At 100x, the nebula breaks up into numerous small intertwining laces that appear to be three-dimensional strands. Between the northern ends of these two objects is even more filamentary nebulosity. The northernmost triangular bright patch is NGC 6979. A careful sweep on a dark night shows the entire glowing sphere of this remarkable object.

The **Egg Nebula** (PK 80–6.1) is an example of a protoplanetary nebula — a star that is entering the planetary nebula phase of its life. Recent images from the Hubble Space Telescope show a nebular cocoon that hides the star. Intense light shines through the thin portions of this shell as if it were emitted from a searchlight. Through an amateur's scope, the Egg Nebula is not a difficult object due to its high surface brightness. One interest to visual observers is its light, which is 40 percent polarized. Rotating a polarizing filter or sunglasses between your eye and the eyepiece will cause the nebula to fade noticeably.

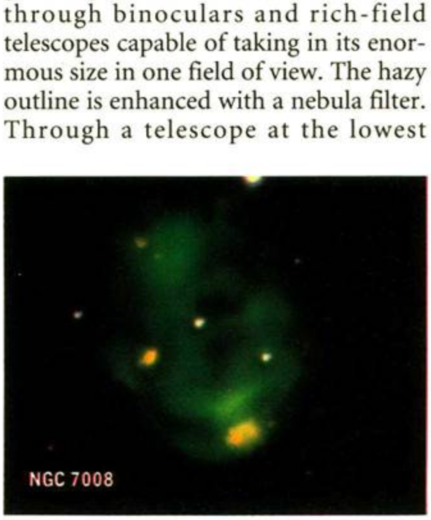
Looking quite like a planetary nebula is the impostor **NGC 6857**. This obscured HII region was misclassified as a planetary until recognized as an emission nebula in 1969. It lies nearly 30,000 light-years away and appears telescopically as a moderately faint, round disk with a diffuse edge.

Our next stop, the **Crescent Nebula** (NGC 6888), will greatly benefit from the use of nebula filters. It is a bubble of interstellar gas some 5,000 light-years away surrounding a Wolf-Rayet star — a highly evolved, white-hot O-type star that sheds powerful stellar winds. This 7th-magnitude star is dead center in the nebula. To view the entire object, use magnifications below 100x. The view through the eyepiece displays a bright, arc-shaped rim on the western edge, with a bar projecting at a right angle to the center and ending near the illuminating star. The nebula's high excitation results in a very pleasing view with a narrow-band Oxygen III filter. With such a filter, the entire footprint shape can be detected floating in a sea of Milky Way stars.

Two degrees south-southwest of Sadr (Gamma [γ] Cygni) is the open cluster **M29** (NGC 6913). Small telescopes seem to do the best job on this object as they isolate the cluster from the confusion of the surrounding field. I counted twenty stars packed into a 5' circle with a square grouping placed centrally. M29 is 5,000 light-years away.

NGC 6826 has been dubbed the Blinking Planetary because of its curious central star. With direct vision, this star is bright and visible, but it becomes engulfed in bright nebulosity with averted vision. The effect holds in smaller apertures, but there's no getting rid of the central star in scopes larger than 8 inches. The planetary's disk is uniform and round, just less than 0.5' across. Like the Ring Nebula, NGC 6826 has a faint halo. This feature is over twice as large and 2,000 times fainter than the nebular core. Planetary nebula halos are the result of their central stars shedding a portion of their mass.

The **North America Nebula** (NGC 7000) is best found at a dark site with only the naked eye. Start by looking roughly 3° east of Deneb (Alpha [α] Cygni). Although the continent's outline is not readily apparent, the taper into "Mexico" is noticeable on good nights. This nebula is best viewed through binoculars and rich-field telescopes capable of taking in its enormous size in one field of view. The hazy outline is enhanced with a nebula filter. Through a telescope at the lowest magnifications, the "Mexican peninsula" is the most prominent. It unmistakably shows up as a sudden brightening of an already starry field.



NGC 7008

Bruce Balick

A 1° sweep to the west of the North America Nebula lands the eyepiece on IC 5067, the **Pelican Nebula**. This piece of nebulosity is fainter and may require a nebula filter to be seen. On the best nights, an 8-inch rich-field telescope reveals signs of the bill of the Pelican as a dark break in the ghostly glow.

The "Little Dumbbell Nebula" moniker is already in use for M76; perhaps "The Tiny Dumbbell Nebula" applies to **NGC 7026**. A 16-inch telescope at 300x on a steady night reveals two lobes that are only 5" across and separated by that same distance. The eastern lobe is slightly brighter and more concentrated. NGC 7026 has a very high surface brightness, making it an excellent object for those steady nights with relatively poor transparency.

The Swan and the Harp

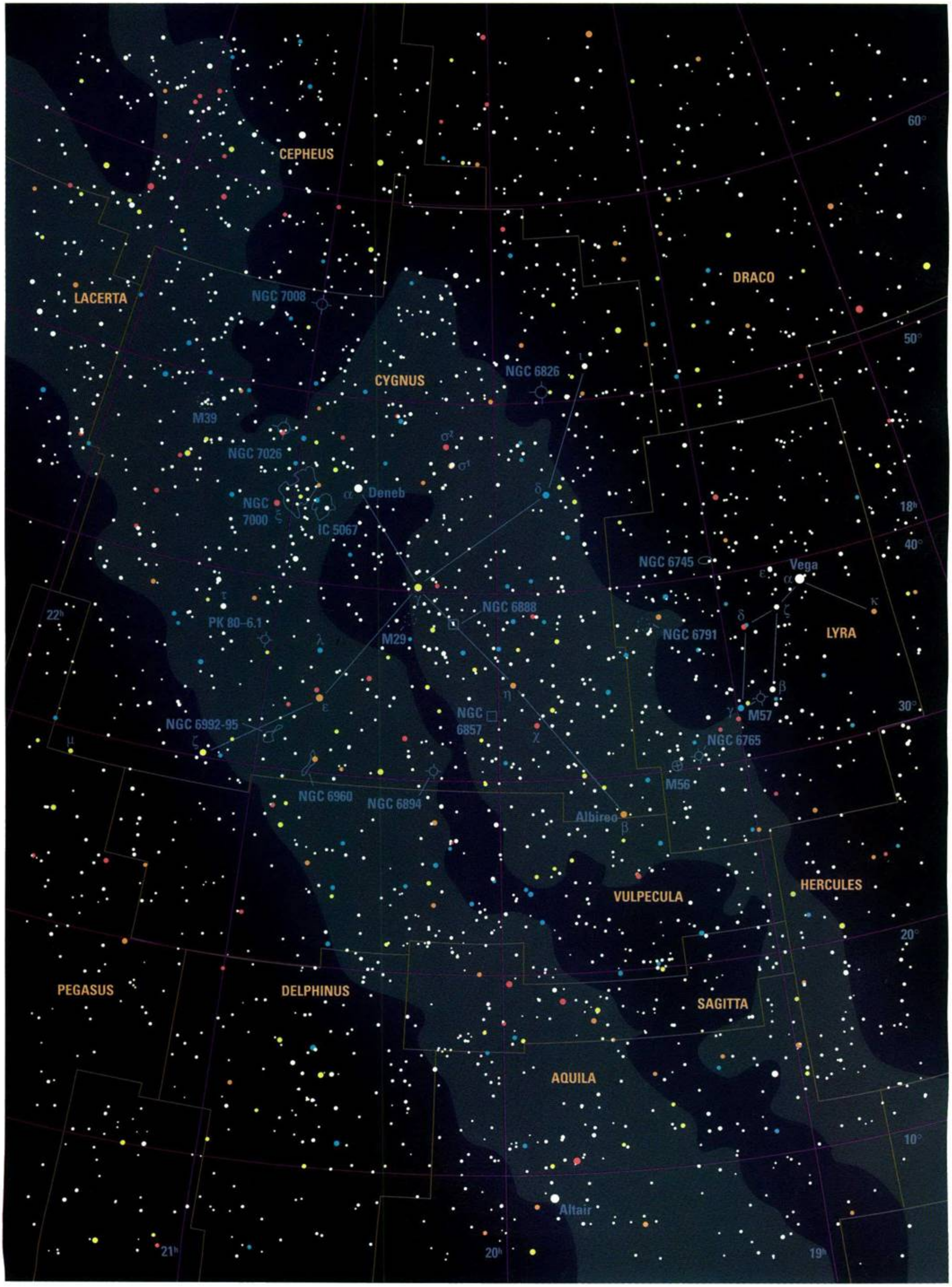
Orion kneeling in his starry niche,
The Lyre whose strings give music audible
To holy ears, and countless splendors more,
Crowned by the blazing Cross high-hung o'er all;
New Year's Eve, 1844 by James Russell Lowell (1819–1891)

Whether the Swan who seduced Leda or the enormous Roc from the Arabian Nights' classic tale of Sinbad the Sailor, Cygnus is a constellation whose representation as a bird predates these familiar Greek and Arabic legends. In Mesopotamia, the constellation was known as the Bird of the Forest. To the Greeks it was Ornithos until Eratosthenes renamed it Cygnus. One seldom-told myth involves Phaethon, the mortal son of Helios and brother to Cygnus. Phaethon tried to drive his father's Sun Chariot for one day, but he could not control the fiery steeds. He raced across the sky leaving a scar across its blackness, a scar we now call the Milky Way. Eventually Phaethon was ejected from the chariot. He fell to Earth like a meteor landing in the river Eridanus. Cygnus threw himself into the river frantically searching for Phaethon. The gods, seeing his sorrow and devotion, took pity on Cygnus and transformed him into a swan. They placed him in the heavens where he now swims along the Milky River still searching for his lost brother Phaethon.

The myths of Lyra are also varied and ancient. Known as the instrument of Mercury, the harp was later given to Apollo who passed it on to his son Orpheus. Orpheus was a great musician who was able to charm the most savage of beasts with his music. The primary myth surrounding the musician involves his wife Eurydice. When she died, Orpheus used his talents to convince Charon, god of the underworld, to let his wife go. The only promise demanded of Orpheus was not to face Eurydice as he led her out of the darkness. He was to play his music as she followed behind. As the couple neared the surface, Orpheus could no longer tolerate not knowing if his wife had followed or not. He turned to face her and she vanished.

The Native American Chumash myths of Cygnus and Lyra also involve the land of the dead. To them the constellations in and around the Milky Way represented challenges only good souls could complete before entering the Land of the Dead (the great rift in the Milky Way). Cygnus was She Who Thunders the Scorpion Woman, and her tail with its stinger was the constellation Lyra.

— Andrea Gianopoulos



CEPHEUS
60°
LACERTA
NGC 7008
DRACO
50°
CYGNUS
NGC 6826
ι
M39
NGC 7026
σ²
σ¹
α
Deneb
δ
NGC 7000
ξ
IC 5067
18h
40°
NGC 6745
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NGC 6791
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NGC 6857
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M57
30°
NGC 6992-95
χ
NGC 6765
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μ
M56
NGC 6960
NGC 6894
Albireo
β
HERCULES
VULPECULA
20°
PEGASUS
DELPHINUS
SAGITTA
AQUILA
10°
Altair
21h
20h
19h

Near the Cepheus border is the fine planetary nebula **NGC 7008**. Todd Gross, through his 16-inch reflector, saw an open ring, moderately large in size, with an irregular, clumpy nature. The southern end appeared to open to two bright stars. His detailed observations at 265x with a full moon in the sky provide another testimony to the merits of high-power viewing. Darker skies may reveal a dim knot 22" northwest of the central star. Designated K4-44, this "knot" is a completely separate planetary nebula.

Our last object is perhaps one of the least spectacular of Messier's objects. **M39** (NGC 7092) is a wide open cluster with little definition. A scope of moderate aperture shows thirty stars between 7th and 13th magnitudes spread over a half-degree field. M39 is 1,000 light-years away.

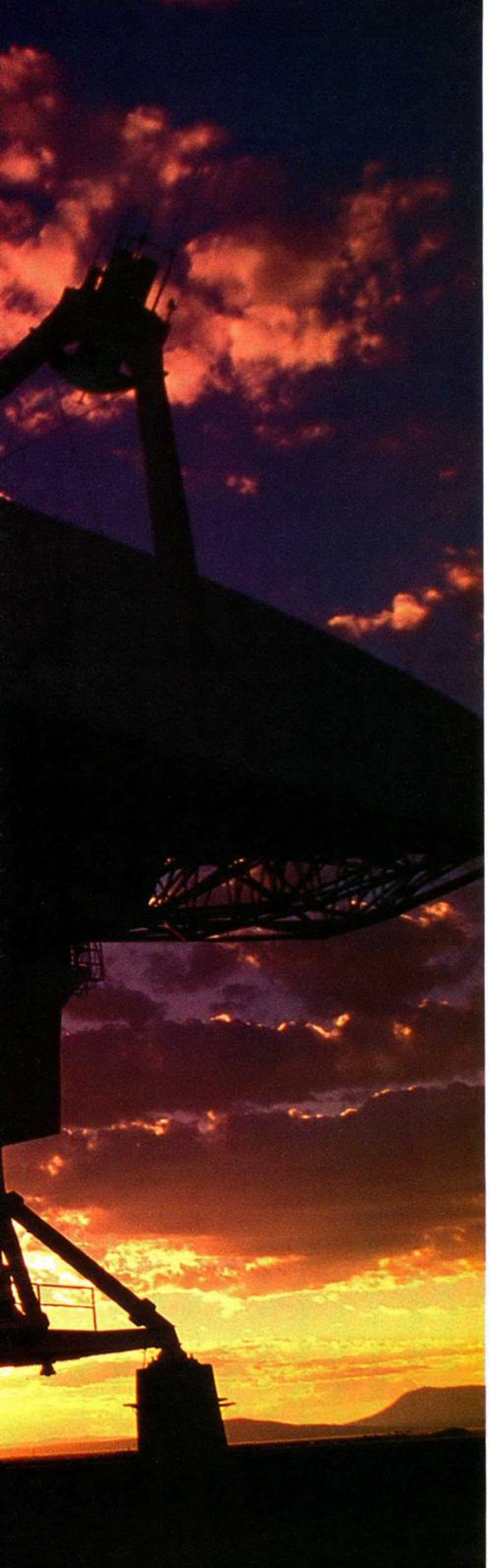
Tom Polakis lives in Tempe, Arizona. His primary astronomical interests are deep-sky observing and photography.

Jack Newton

Deep-Sky Objects in Cygnus and Lyra

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep./Per.	Type	Notes
Epsilon Lyrae	18h44.4m	39°39'	5.0,6.1/5.5,5.5	2.6"/2.3"	Dbl	
IC 1296	18h53.3m	33°03'	14.8	0.9' by 0.5'	Gal	SBb
M57	18h53.6m	33°02'	9.7	71"	PN	Ring Nebula
NGC 6745	19h01.6m	40°45'	12.3	1.4' by 0.7'	Gal	—
NGC 6765	19h11.1m	30°33'	12.9	38"	PN	
M56	19h16.6m	30°11'	8.3	7.1'	GC	Conc. = 10
NGC 6791	19h20.7m	37°51'	9.5	15'	OC	300 stars
Beta Cygni	19h30.7m	27°58'	3.1,5.1	34"	Dbl	Alberio
NGC 6826	19h44.8m	50°31'	8.8	25"	PN	
NGC 6857	20h01.9m	33°31'	11.4	38.0"	DN	
NGC 6888	20h12.8m	38°21'	—	18' by 13'	DN	Crescent Nebula
NGC 6894	20h16.4m	30°34'	12.3	42"	PN	
M29	20h23.9m	38°32'	6.6	6'	OC	
IC 5067	20h50.8m	44°21'	—	25' by 10'	DN	Pelican Nebula
NGC 6960/92–5	20h51.1m	31°03'	—	3°	DN	Veil Nebula
NGC 7000	20h58.8m	44°20'	—	120' by 100'	DN	North America Nebula
NGC 7008	21h00.6m	54°33'	10.7	83"	PN	
PK 80–6.1	21h02.3m	36°42'	13.5	16.0"	PN	Egg Nebula
NGC 7026	21h06.3m	47°51'	10.9	21"	PN	
M39	21h32.2m	48°26'	4.6	31'	OC	

Object: Designation in Messier, NGC, or other catalog. **R.A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./ Per.:** Size in arcminutes or arcseconds, separation in arcseconds, or period in days. **Notes:** Hubble type for galaxies or type for variable stars.



Eavesdropping *on the* Cosmos

Take a trip to New Mexico to visit the Very Large Array, where an army of gigantic radio telescopes listens for whispers in space.

by Nancy L. Hendrickson

THEY STAND ON THE SITE OF AN ANCIENT INLAND SEA, SCANNING the horizon with the same unblinking posture as the stone heads of Easter Island. Within their shadows, cattle graze on high desert scrub, clomping about amidst late July wildflowers. Here and there big-eared jackrabbits stand stone-still, as highly attuned to nature's whispers as the 230-ton radio telescopes towering over them. This is the home of the Very Large Array.

Located in a region where Loretta Lynn trounces Madonna on the local airwaves, it seems too backwater, too cowboy to host one of Earth's most sophisticated astronomical radio observatories. The juxtaposition is something like being served a ladle full of chicken gravy atop raspberry frappe. While that culinary combination probably wouldn't find takers in most restaurants, the VLA's shocking combination works just fine. In fact, precisely because the VLA is so very remote, you feel there as though you've time-warped to a futuristic robotic city.

And if a remote locale is what the National Radio Astronomy Observatory (NRAO) sought when looking for a place to build the VLA, they certainly found it. It's off the beaten track — high, dry, and distant. An hour west of Socorro, New Mexico, you won't stumble onto their property by a quick exit off the interstate. At an altitude of 7,000 feet, the Plains of San Augustin are just about perfect for grabbing incoming radio waves from "out there." The altitude and dry air minimize atmospheric blurring, and the mountains block out the man-made radio signals we humans clamor after. Sitting at a latitude of 34° almost 85 percent of the sky is within their reach, including the center of the

A brilliant southwestern sunset provides a dramatic backdrop for the giant white radio antennae of the Very Large Array. All photos: Nancy L. Hendrickson galaxy — a good thing, because when you're chasing the secrets of the universe, you need all the breaks you can get.

I was only two years old the last time I traveled to New Mexico, years before anyone had even conceived of the VLA. As my 50th birthday crept up, I thought it would be fun to celebrate in the state that was whooping it up over another 50th anniversary — Roswell's UFO crash. It seemed appropriate since I got my first taste for science via the movie classics of the 1950s — *Invaders from Mars* and *The Thing* (two movies I still cannot watch if I'm alone in the house). Couple that with the fact I'd just seen the movie *Contact*, and I knew there was no postponing this trip.

Drive, don't fly, when you visit New Mexico. At 30,000 feet you may have friendly flight attendants offering complimentary beverages, but you'll miss the culture clash taking place on the ground. In the north, chic cowboy boots and silver jewelry have found homes in trendy Indian galleries, which have turned dusty pueblos into a Chamber of Commerce dream come true.

In the south are the vestiges of the science that took place during my own lifetime, the names now a part of our collective memory: Trinity, Alamogordo, White Sands, Los Alamos. Here, too, are treasures you'll never see from the sky — Deming's Great American Duck Race, the Old Town of Las Cruces, rattlesnake eggs, and insect larvae candy. Twenty-year-old issues of *True West* magazine are sold on a counter not ten feet away from Chinese fireworks that could make you forget how much you miss Comet Hale-Bopp.

Driving north to the VLA from Las Cruces, via San Antonio and Socorro, you'll experience a desert unlike those of the neighboring states Arizona and Texas. The hues are softer here . . . sage, wheat, and wind-scoured khaki. But don't be fooled by the softness . . . just south of San Antonio is a stretch of desert so deadly it earned the name Journada del Muerto — Journey of the Dead. During the rainy season, late afternoon squalls blow through with ferocity, spiffing up the landscape like a mother putting finishing touches on her churchgoing kids.

Plan on arriving in San Antonio at mealtime and head straight to the Owl Bar and Cafe. It's been serving up hotter-than-you-know-what green chili cheeseburgers since the 1940s. Back then, nuclear scientists on their way to White Sands from Los Alamos made the Owl a regular watering hole, and it's still worth a visit. It's dark inside, a welcome respite from the 95° F temperature threatening to melt the pavement outside. The Owl's hardwood bar practically fills the room, a behemoth scavenged from a nearby boarding house — the first Hilton Hotel. Wallpapering the walls and ceilings are one-dollar bills, each bearing sentiments from their former owners. "Thelma and Louise Live" was my personal favorite. Don't walk in expecting Limoges china though: You'll find paper cups, paper plates, and flaming hot chili peppers mixed in burgers and served on flame retardant buns. Bring Kleenex.

After you've eaten your fill at the Owl Bar, travel ten miles or so up the highway to the old mining town of Socorro, where you'll need to turn west on US 60 to reach the VLA.

On first sight, be prepared to be stunned. Dotting the vast Plains of San Augustin are gleaming white giants, all staring at exactly the same portion of sky. I felt like I'd stumbled upon the silent Centurion Guard of some future galactic emperor. There are 27 in all, positioned along 85 miles of railroad track. The only thing wrong with the picture was that it didn't match the photos I'd seen. I remembered the antennae as being spread out over miles, and yet I could get several of them in my camera viewfinder. Then the reason for the railroad tracks became clear: The dishes aren't stationary.

While optical telescopes have been around for centuries, radio telescopes are fairly new on the scene. Karl Jansky built the first one in the 1930s while trying to discover the source of radio waves that were interfering with transatlantic communication. He detected the source — the center of the Milky Way. Within the next 20 years, scientists discovered

In characteristic bovine oblivion, these cows seem to be wholly unperturbed by their high-tech neighbors.

National Radio Astronomy
OBSERVATORY
NRAO
VERY LARGE ARRAY
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ASSOCIATED UNIVERSITIES, INC.
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NATIONAL SCIENCE FOUNDATION

that the resolution of a large radio telescope could be simulated by combining incoming signals from several antennae separated by a great distance. The 27 antennae at the VLA, for example, work together to produce radio photographs that could only be accomplished with a single dish if it were 20 miles in diameter.

Entering the VLA's property, you know right off these folks take their radio waves seriously. No cell phones or microwaves, please. My first stop was the Visitor Center for a 15-minute get-acquainted slide show. Then I went into the exhibit room, which details the history of radio astronomy and the workings of the VLA. I saved the self-guided walking tour for last.

For those of us more accustomed to visual cues, it's hard to comprehend a radio sky. According to the guidebook, if we could see radio waves instead of light, our daytime sky would be as dark as night. We'd gaze at glowing emissions arising from clouds of interstellar gas or cosmic rays that swarm along magnetic pathways. What wondrous new constellations we'd spy.

Don't be surprised if you're the only one there when you visit. In the several hours I was on site I only saw three other visitors and a couple of maintenance men. Most of the time I felt like I was walking through an otherworldly ghost town. I bet the VLA could raise lots of extra money by staying open on Halloween night and scaring the heck out of everybody. That's the kind of place it is.

Though most of us are familiar with the rotating domes of optical telescope observatories, we're less familiar with the big dishes of their radio astronomy compadres.

Instead of analyzing light waves, the scientists here study radio waves emitted by celestial objects. Using the 27 dishes working in concert, detailed images can be produced of extremely faint objects.

The incoming signals are sent through a hollow pipe called a wave guide and from there into a correlator, which assembles the data into a useable form. Stored on magnetic tape, the data can be used to create a radio image long after the actual observation is made.

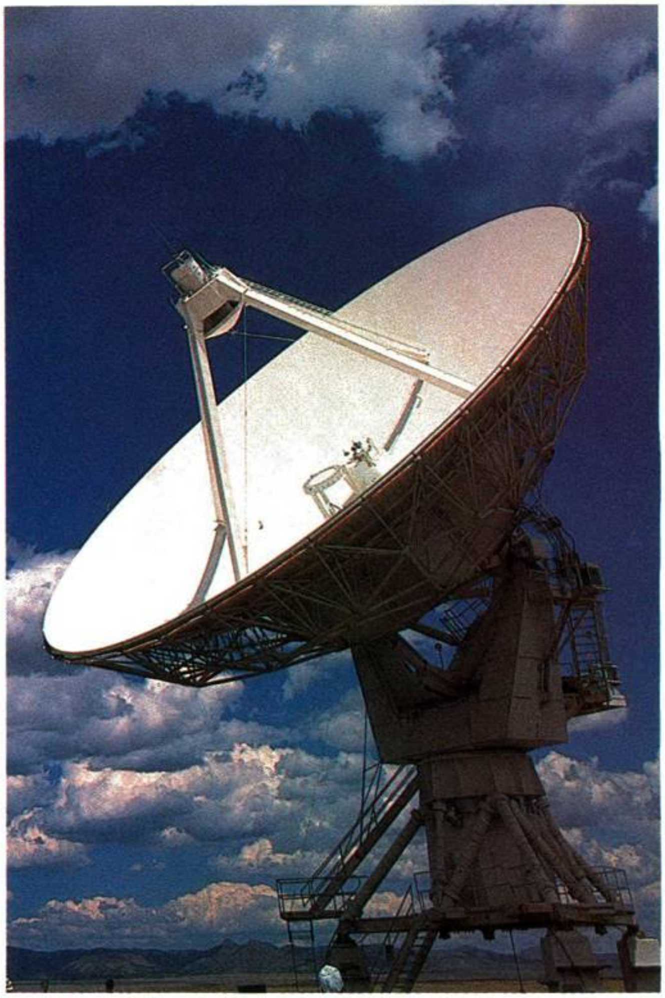
The dishes are arranged in a Y-shape, with nine radio telescopes per arm. Resolution is achieved by changing the distance between scopes. In the "A" configuration, the scopes extend over the 13-mile length of each arm, resulting in the largest magnification. The resolution is the equivalent of seeing a golf ball at a distance of 100 miles. The "B" and "C" configurations give intermediate resolution, and the "D" configuration (the scopes are placed within 0.4 mile of the center) provides the smallest. Changing the distance between dishes produces the same effect as using a zoom lens on a camera. It takes about 16 months to cycle through all four configurations.

Scientists wanting to use the facility submit a proposal describing their research and anticipated observing time. Projects at the VLA can vary from half an hour to several days, with most observing runs having only one or a few target sources. Additionally, the array can be broken into as many as five sub-arrays, each observing a different object at a different band.

Though you can't walk out among all the scopes, the self-guided tour does take you right next to one of them. And standing beside just one of the dishes, each of which are an incredible 94 feet tall and 82 feet in diameter, it's almost impossible to comprehend how powerful the array must be when all 27 dishes work together. And it doesn't stop there. Keeping in mind that the resolving power of the array

Visitors to the VLA are welcomed by the National Radio Astronomy Observatory sign (left).

Each of the array's 27 dishes is an astounding 94 feet tall and 82 feet in diameter. The self-guided tour, though it doesn't allow you to walk among all the scopes, does take you right beside one (below).



increases with the distance between dishes, imagine part of the array being located in space. You really don't have to stretch your imagination too much — it's there now.

In July 1997, the VLA worked with other ground-based facilities and the Japanese HALCA satellite to produce the first images using a radio telescope antenna in space. VLA astronomers digitally combined signals from the satellite and the ground scopes to create a radio telescope which was, in effect, more than two and a half times the diameter of Earth. One of the first targets, quasar 1156+295, located 6.5 billion light-years away, was previously imaged by ground-based radio observatories and showed an elongation in its structure to the northeast of the core. Now, the space-ground system shows the quasar to have both a core and a complex jet emerging from the core, information not previously known. Radio astronomers are expecting to routinely produce images with more than 100 times the detail recorded by the Hubble Space Telescope.

Yes, indeed, these folks take their radio waves seriously.

Toward the end of the self-guided tour you can walk across the balcony of the Control Building. In the rooms on the other side of the hard-to-see-through glass are the central electronics, control, and computer rooms. If you saw *Contact*, you saw what it looks like in there, although for the movie a replica control room was built just outside the real one. The VLA couldn't close down even for a movie.

From the Control Building balcony you're parallel to the array's east arm and just off kilter to the north branch. As I gazed out over the modern monoliths braced upon this ancient seabed, I couldn't help thinking of the odd disparity that had dogged me this trip. If a Cretaceous-era cousin of the cormorant landed in the field beyond, it would have seemed just as fitting as the hawk that wheeled overhead today. It was . . . well, just right. ■

Nancy Hendrickson is a freelancer who loves to travel the West discovering astronomy's most awe-inspiring sites. She co-authored, along with David Cortner, Eight Easy Observing Projects for Amateur Astronomers. *Reach her by e-mail at stjoemo@ibm.net.*

The Very Large Array is located an hour west of Socorro, New Mexico, off US 60. The facility is open daily from 8:30 a.m. to twilight, and admission is free. The Visitor Center has restrooms, water fountains, and a soft-drink machine. There is a picnic area along the self-guided tour. No food is available on site, but there are restaurants in Magdalena, 25 miles east.

Because of the elevation, snow is possible from September through May. In the summer, bring plenty of water as the heat and the altitude can work quickly to produce dehydration.

The Owl Bar and Cafe is in San Antonio, at the intersection of NM 1 and NM 380. It is open daily except Sundays.

The dishes of the VLA can be spread over miles and are rotated regularly through four configurations.

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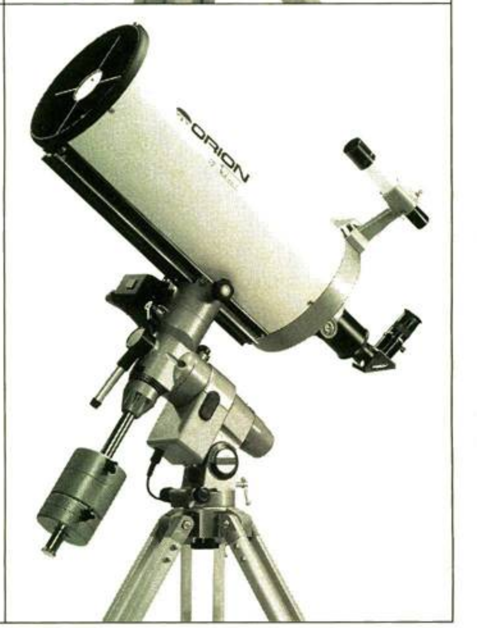

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LUNAR MUSINGS

Awash in a Sea of Crises

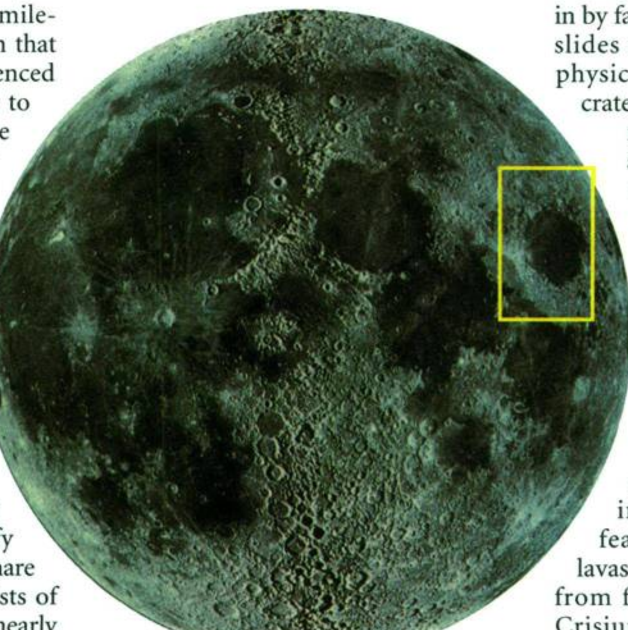
The moon's east end presents a fascinating lava-filled basin for the telescopic observer.

by Jim Bell

I ALWAYS ENJOY MY FIRST GLIMPSE of the young moon; its slender crescent form and the ashen glow of reflected earthshine provide both a lesson in geometry and a reminder of the beauty and grandeur of the night sky. One of the first features that an observer with keen eyesight or equipped with binoculars or a small telescope notices is a dark circular region near the center of the crescent limb. This is Mare Crisium, the Sea of Crises. Crisium is a 300-mile-wide (500 kilometer) impact basin that provides both novice and experienced moon watchers with an easy way to monitor the changing nature of the lunar surface during the first few weeks of the lunar day.

To get a feel for how this huge crater fits into, and in many ways dominates, the overall geology and topography of the moon's eastern limb, start your exploration of the Crisium region with binoculars or a telescope with a wide-field eyepiece. The basin is composed of several sets of concentric ring-like hills. The inner ring, which is easiest to identify because it defines where the dark mare meets the bright highlands, consists of arcuate peaks or massifs that are nearly continuous except for a gap along the far eastern edge of the basin. The next ring out is approximately 295 miles (492 km) in diameter and consists of irregular massifs best exposed west of Crisium from the craters Cleomedes to Tisserand to Proclus. This ring is separated from the inner ring by deep irregular depressions, some of which appear to have mare fill on their floors.

The more distant Crisium basin rings are harder to detect because they have been partially destroyed by craters and basins formed after Crisium. Concentric mare-filled regions like Lacus Bonitatis, the eastern edge of Mare Tranquillitatis near Sinus Amoris, and the northern boundary of Mare Fecunditatis define rings centered on Crisium and have diameters greater than 600 miles (1,000 km). The changing perspective gained by watching the topography in this region over several nights will help you to spot these elusive outer rings.


Lick Observatory

Crisium's complex basin ring system highlights a debate among astronomers about the formation of large impact basins on the moon and planets. Some believe that the mare-filled inner boundary of basins like Crisium defines the maximum size of the crater formed by the impact event and that structures outside of this radius are formed by shock or tectonic processes. Others believe that the original crater formed by the impactor may have been much larger, having a transient crater cavity, perhaps nearly twice as large in Crisium's case, which was partially filled in by fallback of ejecta and/or later landslides or tectonic effects. While the physics of how simple, bowl-shaped craters form is fairly well understood, much remains to be learned about large basin-forming cratering events. Perhaps your own observations of lunar impact basins may help to shed some light on this debate.

Going to a higher resolution telescopic view or examining any of the variety of spacecraft images of this region obtained by the Lunar Orbiter, Apollo, or Clementine spacecraft yields a rich variety of impact, tectonic, and volcanic features. The several-mile-thick lavas on the floor of Crisium are far from flat: Just after the sun rises in Crisium is the best time to view the various wrinkle ridges within the basin. Some of these ridges, also known as dorsa, crisscross the center of the basin while others form an almost concentric ring near the mare/highlands boundary. A dramatic example of a several-hundred-meter-high circular lava cliff or mare bench along the western edge of the basin can be seen just after full moon as the sun is setting in

Crisium. This type of feature may be evidence of additional basin ring structures formed in the original impact event but which have since been buried by the volcanic flooding that occurred later in the moon's history.

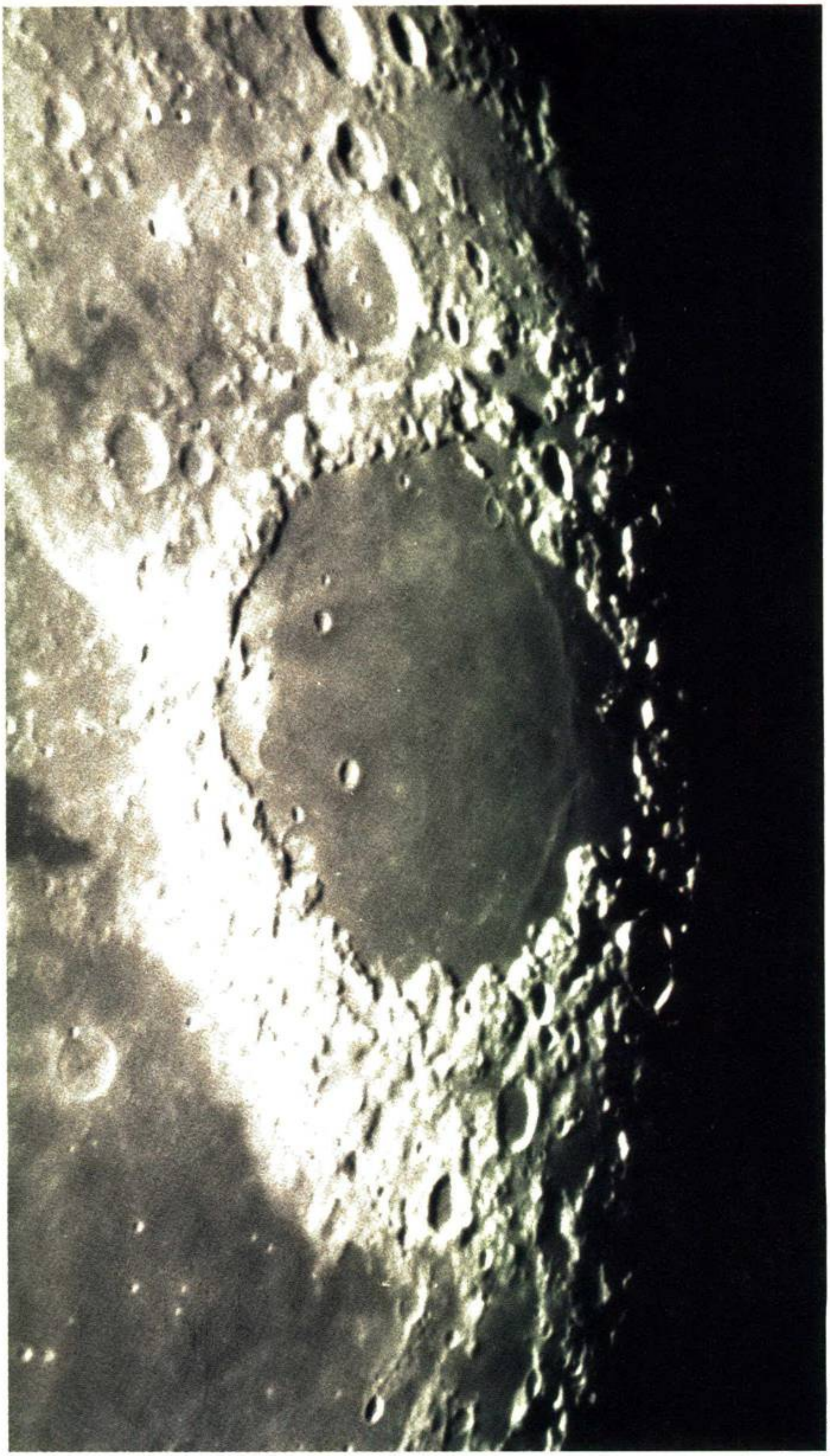
Several *small* but prominent craters within Crisium show dramatic (for the moon at least) color and brightness differences in their ejecta deposits. The two most striking are Peirce (12 miles [20 km] in diameter) and Picard (14 miles [23 km] in diameter). Both of these craters were formed near the edge of the mare deposits, and they have apparently dug down beneath the thin upper layers of lava in these regions to expose older, darker, and bluer lavas and possibly even some highlands materials.

Peirce and Picard provide perfect examples of how astronomers use craters to probe the stratigraphy of the moon, taking advantage of their ability to dig deeply into the lunar crust and upper mantle and to expose materials that are normally buried from view.

A third small crater, Proclus (17 miles [28 km] in diameter) provides another striking example of how impacts continue to modify the moon's surface. After slamming into part of one of the rings of massifs that surround Crisium, this young crater scattered bright highlands-rich ejecta across much of the central eastern limb. Near full moon, Proclus's bright and asymmetric system of rays (likely caused by an oblique impact from the southwest) provide a radiant reminder of the force of cosmic collisions and of their important role as the primary geologic process on the moon today.

It is worth noting that many of the so-called Lunar Transient Phenomena, or LTPs, reported by observers over the past few centuries occur in Crisium and especially near and around Picard Crater. Variously described as mists, hazes, fogs, or anomalous brightenings, many LTPs originate from a combination of atmospheric, instrumental, and observational effects, though some remain unexplained and a few have even been crudely documented photographically.

While no evidence to support the notions of active lunar volcanism, outgassing, or other lunar atmosphere effects has been provided from Apollo overflights or Soviet Luna landings and sample return missions in and around Crisium, the concentration of LTP reports in specific areas like Crisium by many diverse and experienced observers over a long period of time is curious and probably deserves additional study.



Lee C. Coombs

The lunar day begins in Mare Crisium, and with each new dawn comes fresh opportunities to familiarize yourself with the geology, topography, history, and mystery of our nearest celestial neighbor. ■

Jim Bell is a planetary astronomer at Cornell University and is a frequent telescopic observer of the moon and planets.

ask Astro

Dobsonian Scopes, Interstellar Travel, Defending Earth.

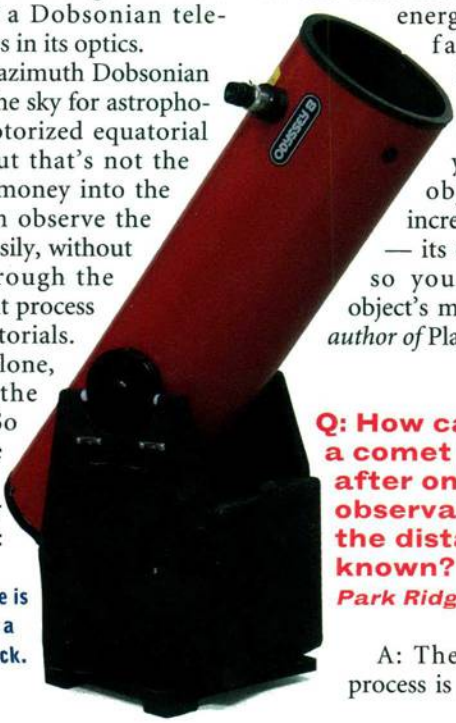
Approximate orbits for comets such as Hyakutake, seen here, can be computed from just three different observations. Michael Stecker

Q: I'm currently in the market for a good yet relatively inexpensive reflector, and I've noticed that a Dobsonian mounted telescope costs substantially less than an equatorial mounted telescope of the same aperture and f/ratio. Is there an optical quality sacrifice involved in obtaining a Dobsonian? — *Rick Patterson, Ashland, Alabama*

A: The price difference can be explained in two words: mount and simplicity. Equatorial mounts have machined, adjustable, and sometimes motorized axes. Dobsonian mounts simply pivot left and right in azimuth while letting the scope they shoulder — with optics identical to equatorials — swing up and down in altitude. With such a simple and straightforward mount, most of a Dobsonian telescope's expense lies in its optics.

Granted, an altazimuth Dobsonian won't track with the sky for astrophotography as a motorized equatorial mount would, but that's not the point. Dobs put money into the optics so you can observe the sky quickly and easily, without having to go through the complex alignment process required by equatorials. For this reason alone, the scope I use the most is a Dob. So don't let the price fool you.

One other piece of advice: Manufacturers often bundle specials in with their scopes. For example, some companies will offer substantial savings on eyepieces or a finder when you buy them with the scope. So if you become deadlocked between two manufacturers, ask about accessory packages. — *John Shibley*



A Dobsonian telescope is easy to use and offers a lot of bang for the buck.

Astronomy

Q: In your article "Interstellar Trekking" (June 1998 issue), you wrote that as a spaceship's speed approaches the speed of light, time slows down and its mass increases. If so, where does the mass come from? — *Sandy Lao, Canoga Park, California*

A: The mass comes from the object's energy. Albert Einstein's famous equation $E=mc^2$ says that mass and energy are equivalent. When you increase an object's speed, you increase its kinetic energy — its energy of motion — so you also increase the object's mass. — *Ken Croswell, author of* Planet Quest

Q: How can the orbit of a comet be calculated after only a few observations, since the distance isn't known? — *Len Kazmer, Park Ridge, Illinois*

A: The whole idea of the process is indeed to attempt to establish the comet's distance. It should be noted that not only is the comet orbiting the sun, but so is Earth. The differing perspectives of observers at different times aid the calculation immensely. Furthermore, if the comet is relatively close, the use of measurements by different observers (even by the same observer as Earth rotates during the night) can yield a moderately accurate value for the comet's distance by triangulation because the comet is seen at slightly different positions against the background stars.

The measurement of the comet's sky position at a particular instant provides two pieces of information: its right ascension and declination. To define the size, shape, and orientation of the comet's orbit in space, and the comet's particular location in the orbit, requires six pieces of information. In principle, therefore, the orbit can be derived from measurements of the sky position at three different instants. The trouble is that the comet's apparent motion between these instants may be too regular, and a large range of distances will fit the data. It therefore helps to assume at the outset that the orbit is a parabola — an ellipse that just reaches infinity at its far end.

The important thing to appreciate is that the initial orbit calculation is just an approximation. As more observations are made, we can see how well the calculated orbit predicts them. Given many observations, we can then use statistical methods to adjust the calculation and continually refine the orbit. — *Brian Marsden, Harvard-Smithsonian Center for Astrophysics*

Q: What might our sun look like in the night sky of a nearby star system, say Alpha Centauri? What constellation would our sun appear in? — *Cal Estrada, Bear, Delaware*

A: Our sun is a near twin of Alpha Centauri A, the larger member of the double star system we call Alpha Centauri. This system is so close to Earth, a mere 4.3 light-years, that Alpha Centauri A is the sky's fourth brightest star, shining at apparent visual magnitude –0.01. The sun is slightly less luminous than Alpha Centauri A, so it would shine a pale yellow-white in the sky of a centaurian planet at magnitude 0.45.

Most of the bright stars that form the constellations are much farther away than Alpha Centauri, so moving only 4.3 light-years from Earth would make little difference. Orion, for example, would appear virtually the same to the unaided eye. Centaurus would appear mightily different however, as it would be missing Alpha Centauri — its brightest star (although the rest of the constellation, as well as the Southern Cross, would appear much the same). However, when the centaurians look in the other direction, they would see our brilliant sun gracing the northern Milky Way halfway between Cassiopeia and Perseus, about 5° northwest of the Double Cluster. — *James Kaler, University of Illinois*

Q: If the Great Red Spot on Jupiter is a massive storm system, why doesn't it eventually dissipate as all storms do on Earth? — *Rick Mangold, Torrance, California*

A: Jupiter's Great Red Spot is a gigantic high-pressure storm system that is sustained by high-speed counter-flowing bands of winds in Jupiter's upper atmosphere. The storm has been visible ever since telescopes were first big enough to see it in the mid 1600s, so it has been raging for centuries and possibly millennia. It hasn't dissipated because Jupiter is made of gas, so there is no solid ground beneath the Great Red Spot. Hurricanes on Earth lose energy and peter out after they make landfall. — *Robert Naeye*

This Galileo image shows Jupiter's Great Red Spot, which is a high-pressure storm system about twice the size of Earth. NASA/JPL

Q: Are there any defense countermeasures in place for neutralizing near-Earth asteroids or comets on a collision course with Earth? — *Chris Shelner, Jenison, Michigan*

A: Although there has been a lot of public discussion about how to protect Earth against impacts by comets or asteroids, we don't today even have a reliable way of detecting a threatening object, let alone a defense system. Only a handful of people — smaller than the staff of one McDonald's restaurant — are searching for potentially civilization-ending asteroids. At the current rate of discovery, it will take more than a century to find all the large (greater than one kilometer in diameter) near-Earth asteroids. Today we have found fewer than 10 percent of them, and so the most probable warning time is still zero — the first we would know of an impact is when we felt the ground shake and watched the fireball rise above the horizon.

If we carried out an extensive survey, we could probably provide decades of warning for asteroids and short-period comets, but only a year or two for long-period comets. If a threat is identified, we have the technology to deflect or perhaps destroy the threatening object using conventional rockets, spacecraft, and nuclear explosives. There is a debate about how far we should go to develop this defense technology in advance, for instance by testing the effect of a nuclear explosion on an asteroid. But such plans are probably premature; you can't shoot 'em down until you find 'em, and the probability of a catastrophic hit in the next few decades is very low. — *David Morrison, Ames Research Center*

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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15mm Panoptic 1¼", 68° field	**$215**
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22mm Panoptic 1¼"/2", 68°	**$285**
27mm Panoptic 2", 68° field	**$335**
35mm Panoptic 2", 68° field	**$365**

TeleVue Warranty may not be valid outside USA.

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$39.50**	1.52"	**$45.00**	1.83"	**$49.50**
2.14"	**$59.50**	2.60"	**$75.00**	3.10"	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$189.50**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain." ***ASTRONOMY*, February 1991**

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

GREATLY ENHANCED DETAIL

"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

BETTER THAN A DARK-SKY SITE!?

"From my light polluted backyard, the view ... was better with the O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." ***SKY & TELESCOPE*, July 1995**

SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

	Premium*
1¼" **LUMICON DEEP-SKY Filter** threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$199.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$199.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16)	**$399.50**
2" Rear Cell Filter, fits SCT's .... Deep-Sky, **$199.50** UHC, O-III, H-Beta,	**$199.50**
1¼" **LUMICON UHC Filter** threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Choice of ***any two*** LUMICON filters (**Save 7%**) .... 1¼" **$185.00**; 48mm	**$370.00**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines .... **1¼" $99.50; 48mm**	**$199.50**
LUMICON Comet (Swan band) Filter .... **1¼" $99.50; 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$7.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$19.50**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$25.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the LUMICON Deep-Sky (DS) Filter.

Specify Lens Size	**H-Alpha**	**(DS)**
46, 48, 49mm	**$59.00**	**$199.50**
52, 55, 58, 62mm	**$69.00**	**$199.50**
67, 72, 77mm	**$79.00**	**$399.50**
82mm (77mm + adapter)	**$89.00**	**$415.00**

Hypered 2415 film, 36 exp .. **$11.95, $3/$32**

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2111 Research Dr. #5A, Livermore, CA 94550
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LUMICON Products catalogue FREE
All foreign orders add 10% ($10 minimum)
California residents add 8.25% tax.
Prices subject to change w/o notice.
Hrs: M-F 9 am - 5 pm, Sat. 9 am - 1 pm

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**

MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$189.50**
48mm Coma corrector/field flattener	**$285**
3X Relay Diagonal (see photo)	**$99.50**
Illuminated reticle eyepiece, pulsed	**$119.50**

Guider for Hasselblad **$489,** Mamiya 645 **$259**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$299,** Mamiya 645 **$98**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10-12" Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) .... **add $179.50**
Adapter for Hasselblad **$399,** Mamiya 645**$149**
Pentax 6X7 **add $139;** Pentax 645 **add $159**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** .... **$119.50** Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.
2. **Cable release** for long exposures . **$9.95**
3. **Declination motor** (state telescope type) **$109**
4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.
5. **LUMICON EASY-GUIDER** (selection to left) .
6. **LUMICON 48mm DEEP-SKY FILTER $199.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

TRY PPF! HYPERSENSITIZED FILM

SR1600
Scotch
1000
TP 135-36

HYPERED FILM IS 2-10X FASTER!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
Kodak PPF-400, THE BEST!	36	**$14.95**
2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Gold 1000 fast, fine grain	12	**$13.95**
Fuji G800 fine grain color neg.	**24**	**$13.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$8.50**

THE AMAZING LUMICON® O-III FILTER™

WHICH FILTER IS BEST?

H-BETA
ICON OIII
MICON H-BE
MICON UHC
OIII
ON DEEP-SKY

These LUMICON filters have revolutionized deep-sky observing. The Oxygen-III filter is the most popular.

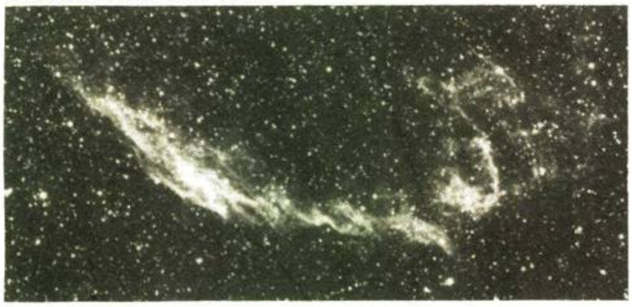
For about 80-90% of all diffuse emission nebulae and about 95% of all planetary nebulae, the LUMICON Oxygen-III filter will give the best view. It is an ultra high contrast nebula filter with a bandpass of only 10nm and 90-97% transmission on the two Oxygen-III nebulae emission lines at 496nm and 501nm.

"VASTLY SUPERIOR"

"The remarkable LUMICON O-III filter is vastly superior to any other filter. It is just amazing. It makes my scope feel twice as large."

Dan Hatton, Ribley, NY

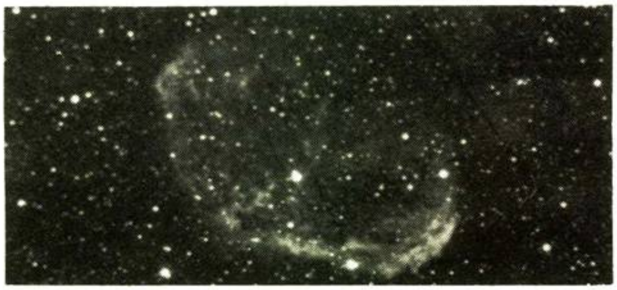
O-III UNVEILS THE VEIL!



"Just for comparison I asked the owner if he had a LUMICON O-III filter. I unscrewed the Orion filter and put in the O-III. The view was improved 100%; the Veil Nebula was stunning!

Brad Franzella, Chico, CA

SEE THE "LITTLE VEIL" TOO!



NGC 6888 in Cygnus, the "Crescent Nebula or Little Veil Nebula." A LUMICON O-III filter is absolutely indispensible to see NGC 6888.

"The O-III shows much more detail and outlying nebulosity in M17 and M8 than any other filter I've tried. It made the extremely faint Cygnus bubble, NGC 6888 ***an easy target****, revealing it as an oval ring with detail visible on one end. It also made the Helical Nebula stand out much better than the UHC or Deep-Sky filters."*

David Knisely, Beatrice, NE

"The LUMICON O-III Filter . . . consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed. From my light-polluted backyard the view . . . was better with the O-III than with any other filter tested. The view was even better than that without the filter from a dark-sky site!"

SKY & TELESCOPE, July 1995

The LUMICON O-III Filter has the highest contrast of any filter made. It is the filter of choice for all knowledgeable deep-sky observers who wish to get the best view of planetary nebulae or diffuse emission nebulae. In fact, after reviewing all nebulae filters made, *Astronomy* magazine reported: *"The LUMICON O-III proved to be our favorite . . . It gave the greatest contrast gain."*

Astronomy, February '91

KEEP UP WITH THE JONES!

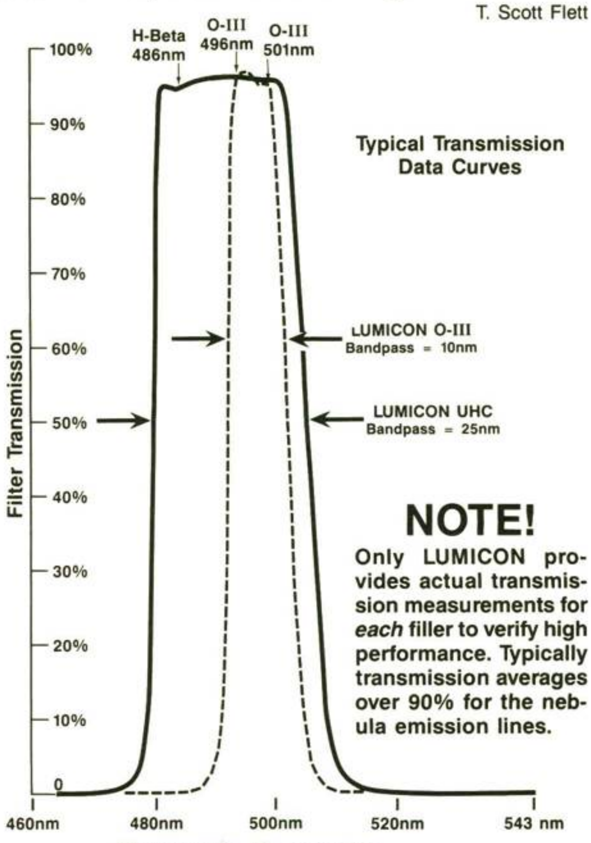
"I took advantage of using a friend's O-III filter to track down the large faint planetary nebula JONES I in Pegasus. In the 12½" two sections of the planetary were seen as arcs almost 180º apart."

Paul Brown, Ontario, Canada

PERFORMANCE EXCEEDS HYPE!

"I ordered your Oxygen-III filter. My first views were from Table Mountain (WA). To say I'm delighted is an understatement. The Oxygen-III is definitely a product where the performance exceeds the hype."

T. Scott Flett



NOTE!

Only LUMICON provides actual transmission measurements for *each* filler to verify high performance. Typically transmission averages over 90% for the nebula emission lines.

Transmission curves for the LUMICON UHC and O-III filters. Notice both have close to 95% transmission for the desirable nebula lines.

LUMICON FILTER SELECTION

	1¼"	48mm	Rear Cell
LUMICON Oxygen-III (O-III) Filter™ *(Select desired filter size)*	$99.50	$199.50	$199.50
Deep-Sky and Oxygen-III Filter™ *(Select desired filter size)* ***Save 11%***	$185.00	$370.00	$370.00
O-III and choice of H-Beta or UHC Filter™ *(Select desired filter size)* ***Save 7%***	$185.00	$370.00	$370.00

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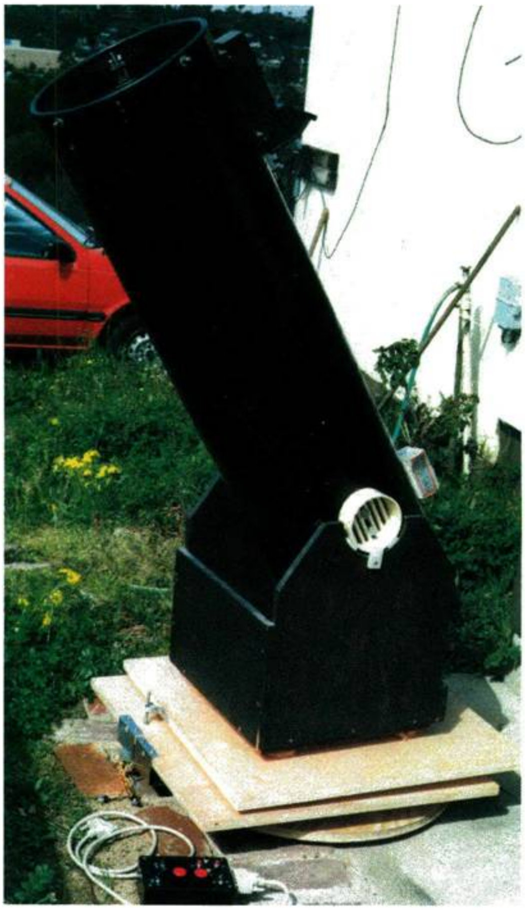
5/98

PRODUCTS

LensPen MiniPro

▶ Dissatisfied with cleaning products for photo and optical equipment, inventors Voytek Wasak and Moshe Cohen-Ravid developed a dry chemical compound and patented the LensPen in 1990 — a unique and revolutionary method of cleaning optic lenses safely and effectively. Now Parkside Optical Inc. is pleased to announce the release of their newest product, the *LensPen MiniPro*. The *LensPen MiniPro* is a smaller version of the earlier product, specifically designed to clean small optical lenses such as telescopes, eyepieces, binoculars, and digital cameras. The *LensPen MiniPro* looks like a pen with a retractable brush at one end and a special circular rubber tip covered by a cap at the other. Users first clean debris from the lens with the brush and then use the tip in a circular motion to absorb oily residue and smears. Manufacturers cite lab tests which confirm that the *MiniPro* is safe for all optical lenses and lens coatings. Additionally, *LensPen MiniPro* is environmentally friendly, uses no solvents, and creates no waste.

International Parkside Products Inc., 1820–1095 West Pender Street, Vancouver, British Columbia, V6E 2M6; phone, (604) 681-6472; fax, (604) 681-6194; website, http://www.lenspen.com. *LensPen MiniPro*: $9.95.



AltAzimuth Platform Kit

▶ With just a little elbow grease, you can assemble your own altazimuth platform — enabling you to track an object for several hours. The *AltAzimuth Platform Kit* from TL Systems provides a full 360° of azimuth movement and 15° of altitude movement. Any slice of the sky at least 15° high can be tracked for several hours, and as is true with any altazimuth mount, no polar alignment is required.

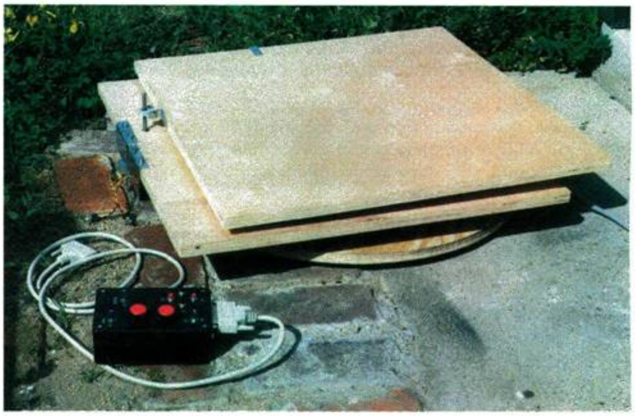
The kit includes all of the mechanical hardware except the wood, and most of the mechanical parts come in sub-assemblies ready for attachment. The kit's altitude and azimuth motor controller circuit boards and stepper motors require 12 volts DC and 250 MA power, which can be supplied either by a battery or an AC-to-12-volt-DC adapter (included in the kit). The platform will support loads up to 150 pounds.

The kit also includes boards to assemble a hand controller (pre-assembled hand control can be purchased for an additional fee), which makes the platform ideal for astrophotography. The hand controller allows users to track bright objects that don't require long exposure times.

An additional kit, the *Autoguider PC Interface Kit*, provides computer autoguiding capabilities. Included are an autoguider circuit board and relay boards to control the azimuth and altitude motors. The autoguider interface will work with CCD Camera Cookbook software or other software capable of controlling the drive motors. The latest version of CCD Camera Cookbook will also allow users to control azimuth speed, altitude, and focus from the computer screen. With Win245 software, drive and focus can be controlled with a mouse.

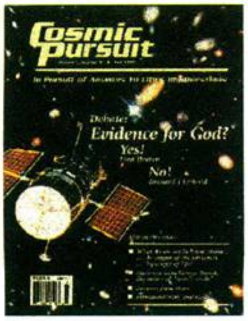
Detailed plans for each step of the assembly process are included with each kit.

TL Systems, 2184 Primrose Avenue, Vista, CA 92083; phone, (760) 599-4219; e-mail, tlsystem@ix.netcom.com; website, http://www.netcom.com/~tlsystem/. *AltAzimuth Platform Kit*: $289; *AltAzimuth Platform Kit with assembled hand controller*: $389; *Autoguider PC Interface Kit*: $269.



Cosmic Pursuit

▶ A new magazine devoted to bringing cosmology down to earth, *Cosmic Pursuit* recently released its third issue. The magazine, the quarterly journal of the Day Star Network, addresses issues ranging from cosmic origins to the relevance of the anthropic principle. Its pages are peppered with short, exclusive interviews with today's top names in cosmology — top theoretical physicists, NASA team leaders, Nobel prize-winning astronomers, and leading scientists in the continuing controversy between naturalists and proponents of intelligent design. The first issue (back issues available) contains a riveting debate on the cosmological evidence for God's existence between science writer Fred Heeren and physicist Bernard Leikind.



Cosmic Pursuit, 326 S. Wille Avenue, Wheeling, IL 60090; phone, (800) 743-7700; e-mail, info@daystarcom.org; website, http://www.daystarcom.org. Annual subscription price: $24.99; special introductory price: $19.99.

The Heavens Declare

▶ Narrated by astronomy writer and lecturer James Mullaney, *The Heavens Declare* is a video production focused on the ever-charged topic of the merger of science and religion. A slide-illustrated tour of the universe portrays its awe-inspiring beauty and order. The narration addresses topics such as the evidence of a Creator, Biblical references to the stars, Genesis and creation theories, NASA astronauts' spiritual experiences in space, prophecy and cosmic cataclysms, and religious and philosophical implications of the search for extraterrestrial life. Directed by Michael O'Donnel, the tape's running time is 82 minutes.

Astronomical Endeavors, P.O. Box 1146, Exton, PA 19341; phone, (610) 269-0047; e-mail, jmullaneysm@msn.com. *The Heavens Declare*: $20 plus $5 S&H.

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Web: www.southernstars.com

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YOUR ASTRONOMICAL FRIEND SAYS
Start now to watch and photograph Sun Spots as they grow toward the next Solar Maximum with our SOLAR SKREEN® Sun Filter on your finder, binoculars or telescope.
SOLAR SKREEN® FILTERS give sharper images of even the smallest Sun Spots than window glass solar filters. Send a large (9x12") SASE envelope (4 stamps) for a FREE sample of SOLAR SKREEN®.
Call 800-223-1063 for details of the
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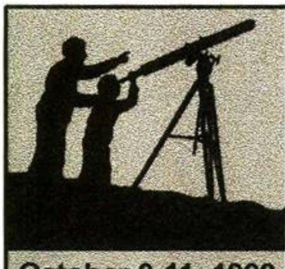
Roger W. Tuthill, 11 Tanglewood Ln., BX
Mountainside, NJ 07092


The 5th Annual
Enchanted Skies Star Party
Astronomy in the Great American Southwest
Join us for observing fun, door prizes, friendly competitions, our famous chuck-wagon dinner, and tours of area scientific facilities. Our renowned lecture series features presentations by amateur and professional astronomers on topics ranging from beginning to advanced observing techniques and the latest news from the cutting edge of science.
The Enchanted Skies Star Party offers a unique experience in Southwestern astronomy. A dry, desert climate, dark skies and Socorro's friendly, small-town environment provide excellent observing and a relaxing atmosphere.
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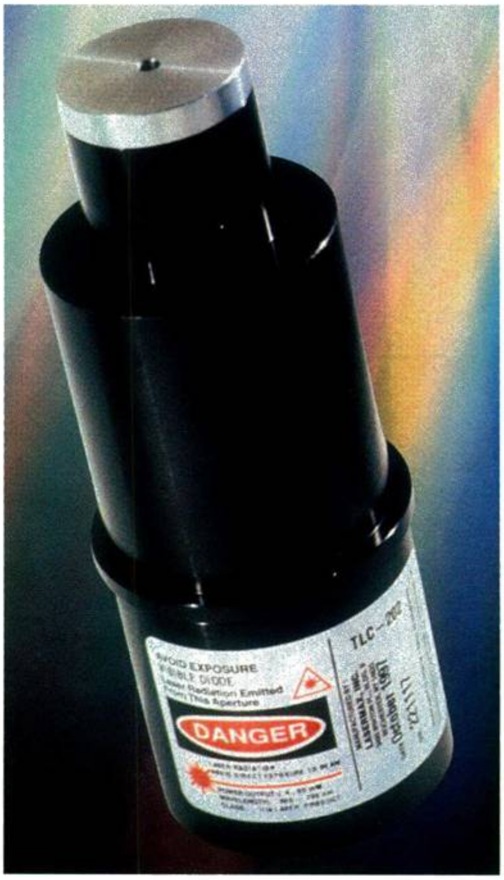
www.socorro-nm.com/starparty.html

TLC Telescope Laser Collimator



▶ *TLC*, a laser/diffractive optic system for Newtonian alignment, is the fastest, most accurate system available to align your large Newtonian telescope. An industrial-quality, self-powered diode laser with a removable holographic diffractive reticle pattern generator, the *TLC* can be inserted directly into the focuser of your scope. This done, adjust the secondary mirror tilt until the reticle pattern is centered exactly on the primary mirror; the primary mirror mount should then be adjusted to reflect the laser pattern back to the *TLC* centered in the eyepiece aperture. In less than one minute, you can quickly troubleshoot and align your Newtonian telescope to the highest level of accuracy in daylight or darkness without prior disassembly or preparation of the telescope. A unique feature of the *TLC* is its projected computer-generated reticle, which combines several images into one standard hologram. The images include a cross hair with micro-graduations, a single-ring pattern for centering the image, a bright central spot, and a low-level diffuse red laser illumination for inspection of the telescope's optical path in total darkness.

The eyesafe *TLC* 5 mW 635 nm laser unit is the brightest laser available in its FDA-regulated safety class (IIIa). Its housing is made of rugged aircraft-grade aluminum, and its optics are designed to withstand an impact of 2,000 G. The *TLC* fits standard 1.25- and 2-inch focus mechanisms. A very high-brightness green laser system, the *TLC-203N*, is also available to use for aligning very large and multiple-mirror telescopes.

LaserMax Inc., 3495 Winston Place, Building B, Rochester, NY 14623; phone, (716) 272-5420; fax, (716) 272-5427. *TLC-202N* (red laser): $295; *TLC-203N* (green laser for larger telescopes): $1,995.

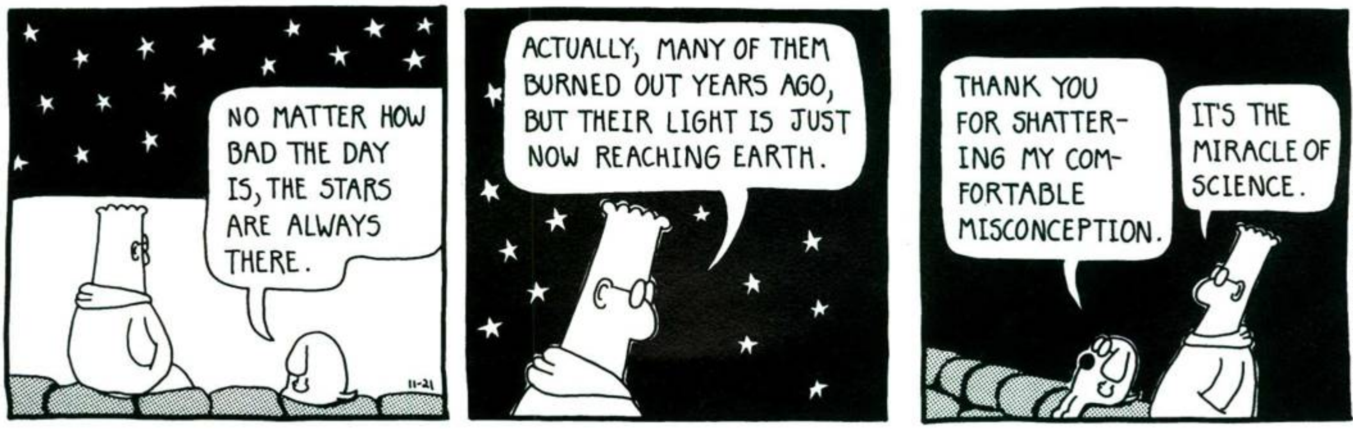
A BOOKS

Other Worlds: The Search for Life in the Universe

Michael D. Lemonick, 272 pages, Simon and Schuster, New York, 1998; ISBN 0-684-83294-1, hardcover, $25.

▶ Ever since Copernicus and Galileo first turned our attention to the expanses of the universe, theorists and the public alike have dreamed of the possibility, however remote, of discovering and contacting alien life forms. For centuries, the possibility that they could be out there somewhere was rejected as unlikely or even childish by the scientific establishment. During our century, a few brave scientists dared to formulate scholarly theories regarding the existence of other planets and solar systems. They questioned publicly that if there could be other planets, then why not other Earth-like planets orbiting sun-like stars and supporting life, perhaps even intelligent life, or perhaps even intelligent life with whom we could communicate.

Although some were willing to accept these theories at face value, scientists in general refused to believe that alien life was probable, or even possible, without some sort of observable evidence. Starting in the 1950s a renegade group of astronomers around the globe started out to find just that piece of evidence — a planet, a solar system, or the Holy Grail of their search, life outside Earth. This group of stargazers quickly attracted experts from the cutting edge of technology. They used telescopes with complicated light sensing devices, dividing starlight into spectra and analyzing the data with computers. In


NO MATTER HOW BAD THE DAY IS, THE STARS ARE ALWAYS THERE.
11-21
ACTUALLY, MANY OF THEM BURNED OUT YEARS AGO, BUT THEIR LIGHT IS JUST NOW REACHING EARTH.
THANK YOU FOR SHATTERING MY COMFORTABLE MISCONCEPTION.
IT'S THE MIRACLE OF SCIENCE.

DILBERT reprinted by permission of United Feature Syndicate, Inc addition, radio astronomers joined in the hunt with their huge listening devices, and with them came an array of mathematicians, astrophysicists, and computer programmers. Also jumping into this new field of study were biologists and organic chemists. They put their expertise in the basic building blocks of life forms as we know them to work to create an entirely new field of study and theory known as exobiology or astrobiology.

Somewhere along the way, the lay person was left out. The dream, which used to belong to anyone who gazed up at the heavens and was willing to let their mind wander freely among galaxies, was now commandeered by lengthy and complex computer programs required to micro-analyze data collected by intricate sensors picking up information all along the electromagnetic spectrum. Theories were encoded in mathematical and chemical formulas unintelligible to even the well-informed public. Discoveries were battered about in scientific debate as soon as they were made public, or even before. The search for ET had essentially gone super-high-tech, out of the ballpark.

Enter Michael D. Lemonick. Lemonick applies a journalist's eye to the situation in *Other Worlds: The Search for Life in the Universe* and gives us a wonderfully down-to-earth look at this high-flying new branch of scientific research. His vast experience as a science writer has given him both a fine understanding of advanced research techniques and the ability to explain them in plain English — without oversimplifying. His years of reporting on these scientists has also given him an "in" to the real people behind the jargon and technology. This is what really sets *Other Worlds* apart and makes it well worth reading — for anyone from other scientists to amateur astronomers to those of us who can't even find the Big Dipper.

Lemonick combines his knowledge of the science with his knowledge of the people and throws in a touch of plain old storytelling. He tells us the stories of individual scientists — their insecurities and hopes, their achievements and failures, and their day-to-day mundane lives. Lemonick has been following their work for years and has come to feel for them and pull for them

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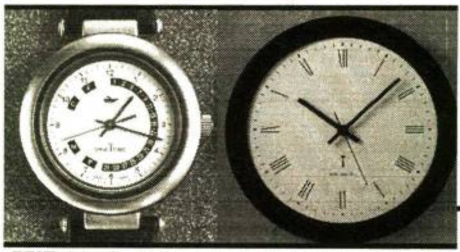

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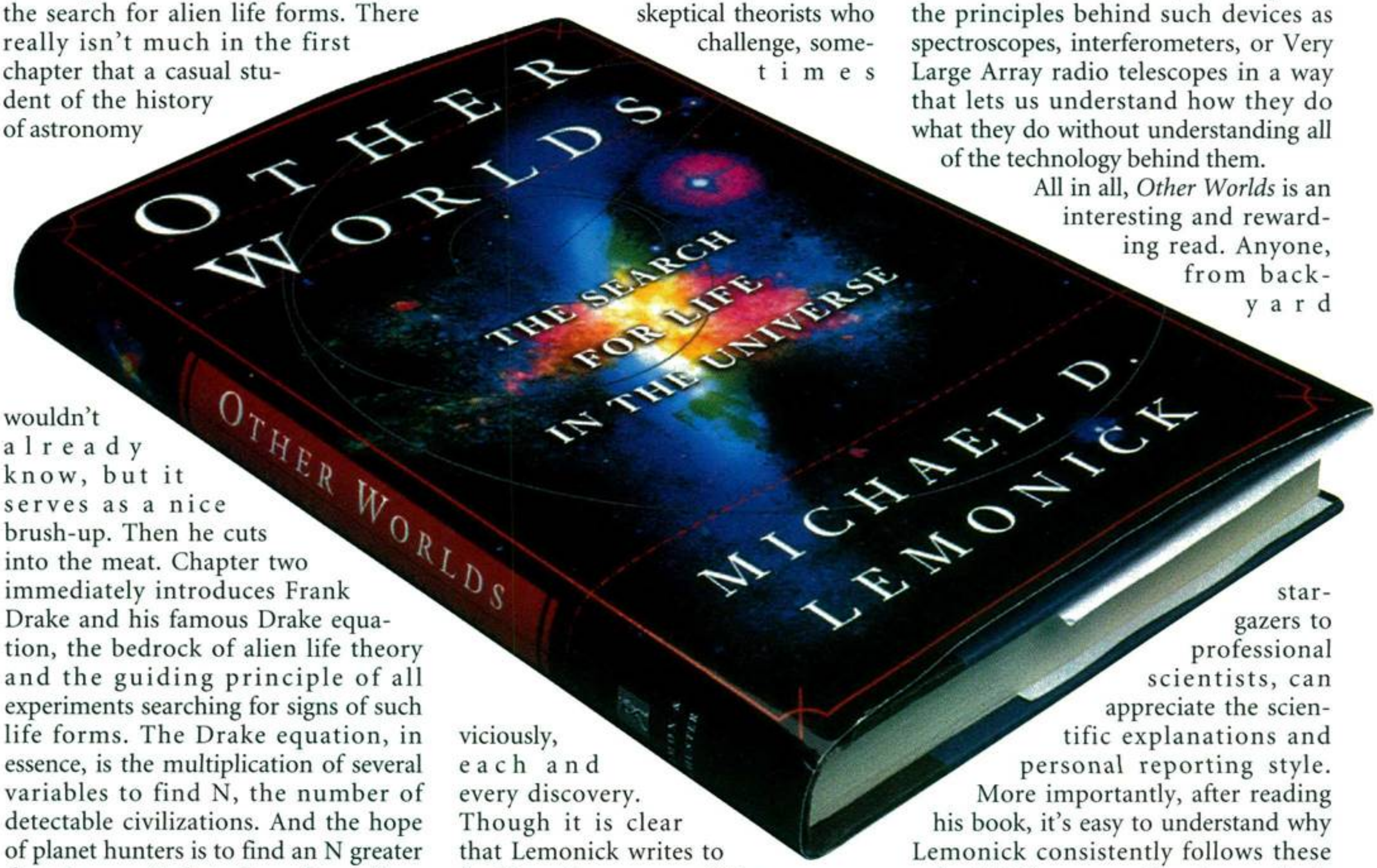

Lemonick gets us ready for this backstage tour with a quick history of the search for alien life forms. There really isn't much in the first chapter that a casual student of the history of astronomy wouldn't already know, but it serves as a nice brush-up. Then he cuts into the meat. Chapter two immediately introduces Frank Drake and his famous Drake equation, the bedrock of alien life theory and the guiding principle of all experiments searching for signs of such life forms. The Drake equation, in essence, is the multiplication of several variables to find N, the number of detectable civilizations. And the hope of planet hunters is to find an N greater than 1 — an N that allows for civilizations in addition to our own. Lemonick continues on from an explanation of the Drake equation to a balanced overview of the different ways in which scientists are breaking it down and searching for life on other planets.

Solving the Drake equation requires that scientists discover more about other sun-like stars — specifically whether there are stars out there orbited by planets. Lemonick starts the journey with the scientists who first found planets outside of our own solar system and who continue to develop new methods for finding more planets, should they be out there. He does not stop with the discoveries of the past, but goes on to describe the new methods and tools that are being planned and developed. He even includes some of the financially and politically impossible telescopes, spaceships, and satellites that these visionary scientists have dreamed up for the future.

Lemonick rounds the stories of these planet-hunters out by recounting some of their notable failures and many of the debates that are raised by skeptical theorists who challenge, sometimes viciously, each and every discovery. Though it is clear that Lemonick writes to further the cause of the planet-hunters, he is inclusive of the entire scientific process, which is dependent not only on research and discovery but also on a reasoned and critical evaluation of that research.

Throughout all of this, Lemonick stays true to his role as storyteller. He never lets the scientific and technical descriptions outweigh the personal. Even when explaining the complex ways in which scientists have managed to measure wobbles of a few meters per second in stars located many light-years away, he still manages to slip in a description of what these scientists look like, what clothes they wear, where they come from, and whether they're bearded or not.

If anything, Lemonick knows too much about these unique scientists. At times he can be easy to lose as he drops names of people and places with the ease of an insider, but this is more than made up for when he describes the technology these scientists use. No big words. No jargon (except for, of course, the acronyms that anyone who deals with NASA loves to use). He explains the principles behind such devices as spectroscopes, interferometers, or Very Large Array radio telescopes in a way that lets us understand how they do what they do without understanding all of the technology behind them.

All in all, *Other Worlds* is an interesting and rewarding read. Anyone, from backyard stargazers to professional scientists, can appreciate the scientific explanations and personal reporting style. More importantly, after reading his book, it's easy to understand why Lemonick consistently follows these scientists' careers: He shares their dream. — *Curtis Baldwin Strohl*

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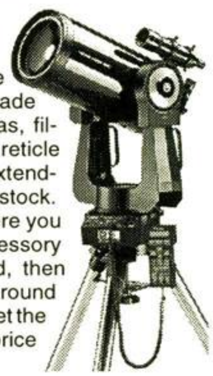

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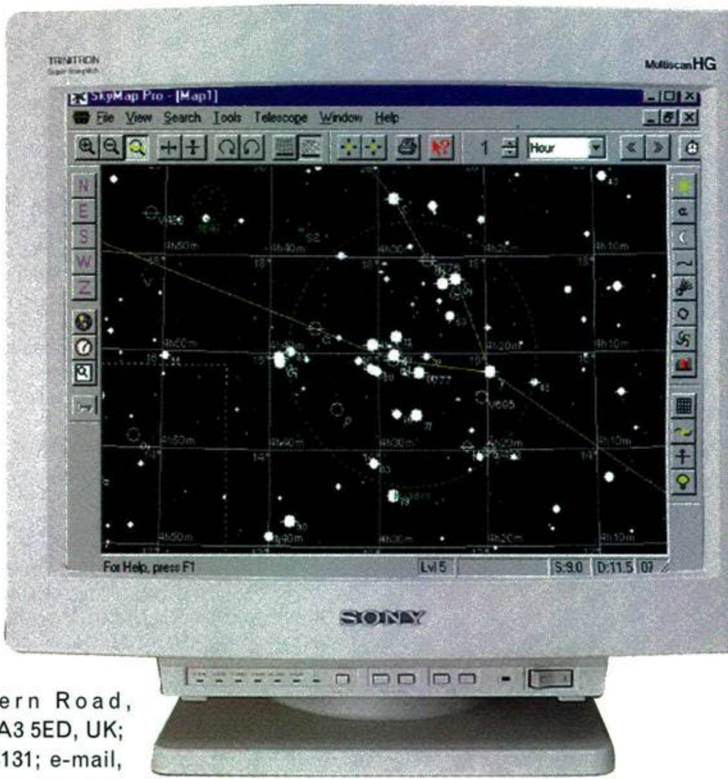

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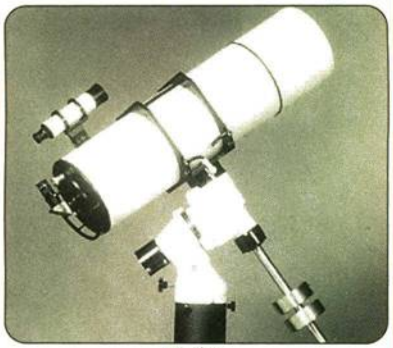

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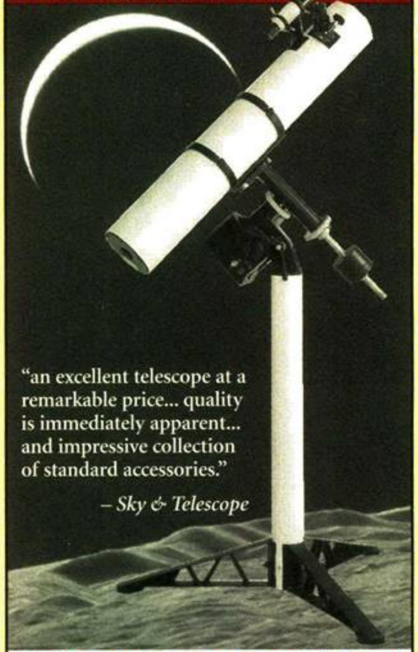

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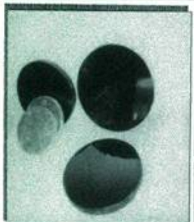

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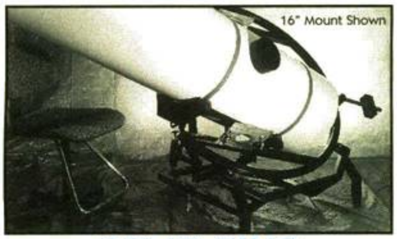

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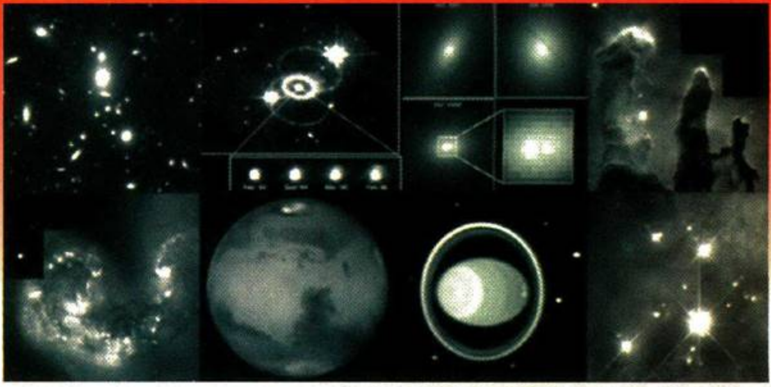

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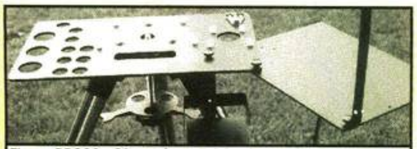

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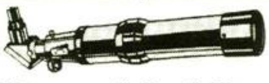

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IN THE AUGUST ISSUE

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Sean Carroll is chasing legs. Using tools of molecular biology, he may have unlocked the genetic toolbox for building limbs.

CARNIVORE COLONIZERS

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LOOKING AHEAD
SEPTEMBER

ASTROFEST '98, TAKING place September 11–13 at Camp Shaw-Waw-Nas-See near Kankakee, Illinois, and hosted by the Chicago Astronomical Society, promises talks by expert professional and amateur astronomers, including *Astronomy*'s Robert Naeye, Andrea Gianopoulos, and Dan Koehler, along with eclipse expert Fred Espenak. There will also be the newest in viewing equipment, astrophotography workshops, telescope contests, and door prizes. For those in the market for new or used equipment, swap meets and more than a dozen vendors will offer bargains and those hard-to-find items. However, with all this, nighttime observing remains the highlight. Last year's event drew more than 800 astrobuffs to the largest star party of its kind in the Midwest.

Vic Winter

Astrofest telescope competitor faces the scrutiny of the judges. (far right: *Astronomy* Photo Editor Patti Kurtz)

THROUGH SEPTEMBER 30
Summer Public Observing
▶ Naperville Astronomical Association's Observatory, Springbrook Water Reclamation Center, Naperville, Illinois. Wednesdays, 7:30 p.m. Contact George Simon, Jr., (708) 983-5029, or Drew Carhart, (630) 978-1133.

SEPTEMBER 4–6
Moore Relic Show
▶ Bell County Expo, Belton, Texas. Meteorites, tektites, etc. Contact Moore Relic Show, P. O. Box 247, Salado, TX 76571; (254) 939–7530.

SEPTEMBER 11–13
AstroFest
▶ Camp Shaw-Waw-Nas-See, Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact Astrofest '98, P. O. Box 596, Tinley Park, IL 60477-0596; voicemail, (773) 725-5618 and press 3.

SEPTEMBER 16–20
Alberta Star Party
▶ Eccles Ranch Observatory, Caroline, Alberta, Canada. Contact Rick and Carol Weis, 4612 17th Avenue N. W., Calgary, Alberta T3B 0P3; (403) 286-4347; fax, (403) 286-2355; e-mail, weisc@cadvision.com; website, http://www.syz.com/rasc/asp.htm.

SEPTEMBER 17–20
Great Plains Star Party
▶ Scopeville, south of Osawatomie, Kansas. Sponsored by the Kansas Astrophotographers and Observers Society. Contact Dan Johnson, (913) 897-0235; website, http://www.icstars.com.

SEPTEMBER 18–19
Abegweit Autumnal Astronomical Adventure (AAAA)
▶ Bayview, Prince Edward Island, Canada. Rain date, Sept. 25–26. Contact Bill Thurlow, 1 Carol Avenue, Summerside, Prince Edward Island C1N 2K5; (902) 436-1083.

SEPTEMBER 18–19
Craters of the Moon Fall Star Party
▶ Craters of the Moon National Monument, between Arco and Carey, Idaho. Contact Jay Sneddon, (208) 736-2447; e-mail, jsneddon@teamamerica.com; or Mark Brandon, (208) 357-3540; e-mail, skygaz@srv.net; website, http://www.geocities.com/CapeCanaveral/Launchpad/2675/cotmstarparty.html.

SEPTEMBER 18–19
Dark Sky Party
▶ Cathedral Gorge State Park, Panaca, Nevada. Sponsored by the Las Vegas Astronomical Society. Contact Jim Mellor, 2052 High Mesa Drive, Henderson, NV 89012; (702) 361-1356; e-mail, jbar2@vegas.infi.net; website, http://www.ccsn.nevada.edu/other/LVAS.

SEPTEMBER 18–19
Nightfall
▶ Palm Canyon Resort, Borrego Springs, California. Contact Nightfall, c/o Fox & Stephens, CPAs, 9045 Haven Avenue, Suite 109, Rancho Cucamonga, CA 91730; (909) 948-2205; e-mail, robert_stephens@eee.org; website, http://home.sprynet.com./sprynet/hrmeyer/nitefall.htm.

SEPTEMBER 18–19
Northern Arizona Star Party
▶ Near Chino Valley, Arizona. Hosted by the Prescott Astronomy Club. Contact Gary Frey, P. O. Box 1114, Mayer, AZ 86333; e-mail, gfreynpo@primenet.com; website, http://www.pgx.com/nasp.htm.

SEPTEMBER 18–20
Connecticut Star Party
▶ Colebrook, Connecticut. Sponsored by the Astronomical Society of New Haven. Contact Bob Carruthers, 37 Saw Mill Drive, Wallingford, CT; e-mail, sunandmoon@freewwweb.com.

SEPTEMBER 18–20

Meeting of the Federation of Amateur Astronomers of Quebec

▶ Mount Cosmos Observatory, St-Elzear-de-Beauce, Quebec, Canada. Contact Jay Ouellet, (418) 688-0763; or Jacques Croteau, e-mail, jcroteau@globetrotter.qc.ca; website, http://www.globetrotter.qc/mtcosmos.

SEPTEMBER 18–20

South Jersey Star Party

▶ Belleplain State Forest, Woodbine, New Jersey. Contact Paul Ostwald, 23 Isaacs Lane, Egg Harbor Twp., NJ 08234; e-mail, paostwald@ aol.com; website, http://members.aol.com/sjastroc/.

SEPTEMBER 18–27

Equinox Sky Camp

▶ Dower House Touring Park, East Harling, Thetford, Norfolk, England. Sponsored by the South Jersey Astronomy Club. For details send a large SAE to Mike Cook, 50 Linley Crescent, Romford, Essex, RM7 8RD; telephone, 0961-832-827.

SEPTEMBER 25–27

Dark Sky Party

▶ Tuckahoe State Park, Queen Anne, Maryland. Contact Frank Sheldon, R. R. 1, Lincoln, DE 19960; or Lyle Jones, (302) 736-9842; website, http://www.dol.net/~frank.sheldon/gazers.html.

SEPTEMBER 26

Island Lake Star Party

▶ Island Lake Recreation Area, Spring Mill Pond section, Brighton, Michigan. Contact the Ford Amateur Astronomy Club, P. O. Box 7527, Dearborn, MI 48121; (313) 390-5456; website, http://kode.net/~dougbock/faac/.

SEPTEMBER 26

North Texas Amateur Astronomers Star Party

▶ Cleburne State Park, Cleburne, Texas. Contact Michael Hibbs, (817) 238-9883; e-mail, Mikehibbs@aol.com.

CONTACT

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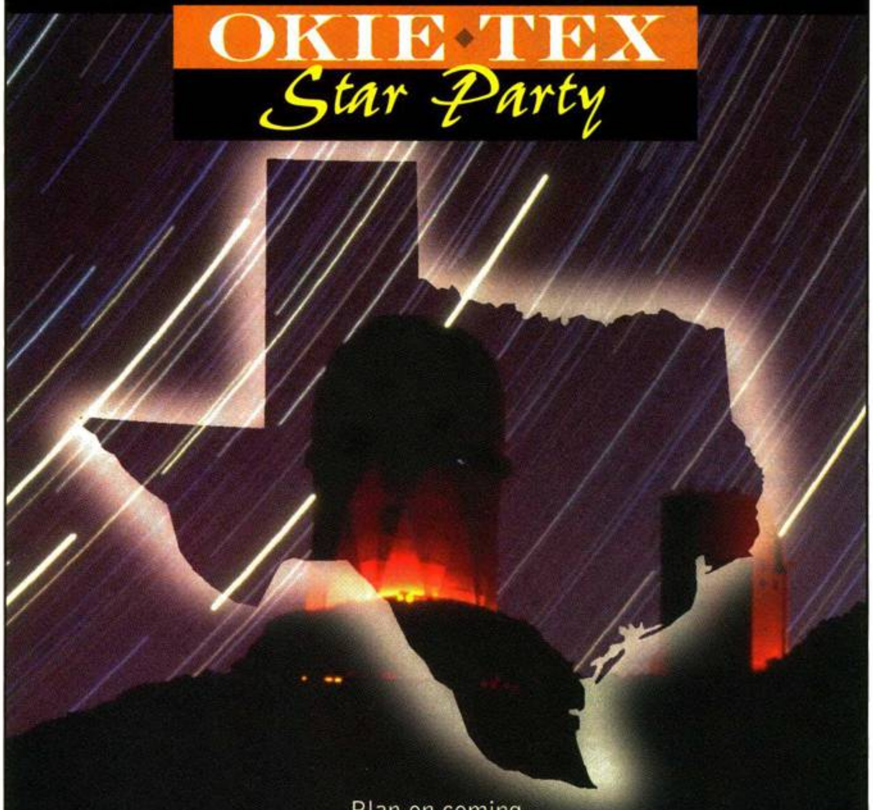

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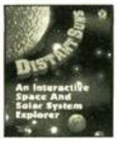

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SO LONG SUMMER SKIES!

Focus on Forums

Regional astronomy forums are all the rage — here's one that keeps getting better.

▶ It began in 1992 — a small show that attracted 250 amateur astronomers from the New York-New Jersey metropolitan area. Today, the Northeast Astronomy Forum and Telescope Show, hosted by the Rockland Astronomy Club of New York, has become one of the nation's premier amateur events. The most recent NEAF, held on May 3, 1998, at the Holiday Inn Conference Center in Suffern, New York, broke all previous attendance records when 1,171 people showed up to browse and shop at the 84 vendor tables and listen to talks presented by six notable amateur and professional astronomers.

They weren't disappointed, and neither were the vendors, who were so busy selling telescopes and accessories that they didn't have a chance to eat lunch. To give you an idea of the NEAF's popularity with vendors, the Rockland Club had to erect a 100-foot tent in the parking lot next to the hotel just to provide shelter to all the necessary tables and displays. When people were not at the tables exchanging cash and checks for equipment, they were entertained by the speakers.

Leading off was Dr. Karl Hricko, a member of Amateur Astronomers Inc., who gave a talk on the "Colonization of Space." Karl was

Star Trails in the Canary Islands

FRANZ KUFER

(40mm lens at f/1, Fujichrome Velvia 50 film, 450-minute exposure)

Gibbous Moon

GREGORY TERRANCE

(6.1-inch f/7 refractor, IMG1300 CCD camera, 0.5-second exposure taken May 19, 1998) followed by Dave Eicher, the managing editor of *Astronomy* magazine, who thrilled the crowd with slides depicting the "Wonders of the Southern Milky Way." After lunch, NASA's Dr. Fred Espenak delivered a fantastic program of slides and videos of his most memorable solar eclipse expeditions.

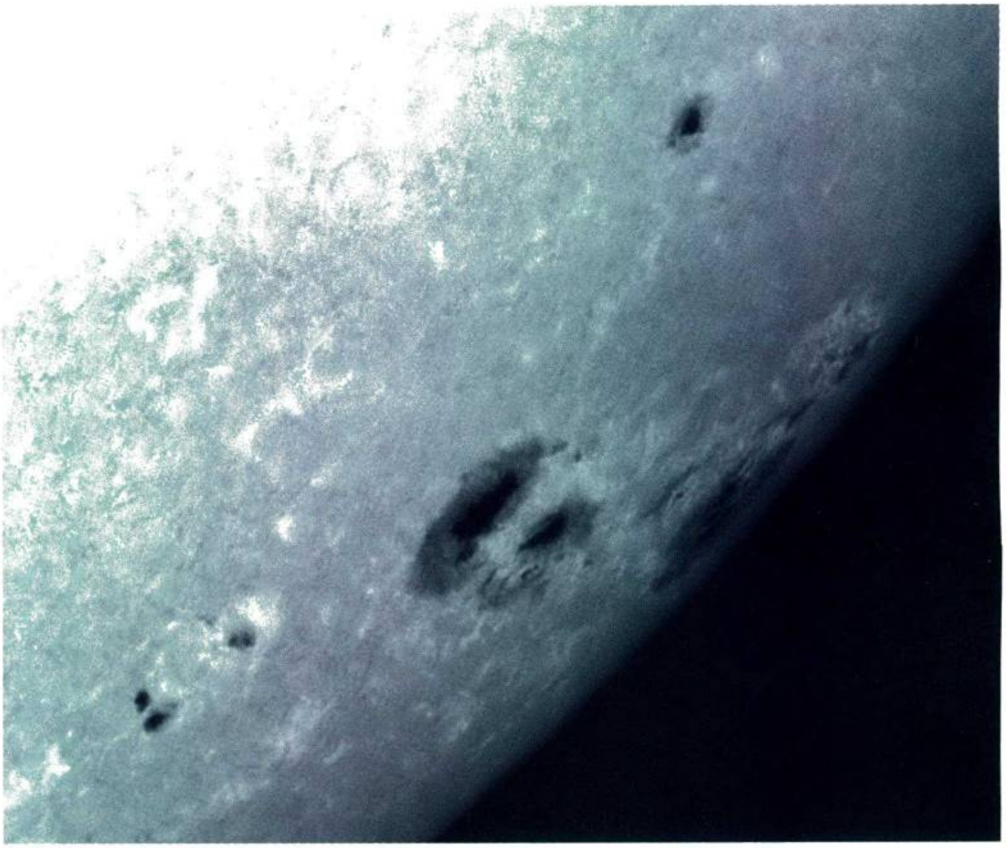
Fred was followed by noted author Phil Harrington, who gave a basic program well suited to those just starting out in astronomy. Roger Sinnott from *Sky & Telescope* then gave everyone the inside story on how the *Millenium Star Atlas* came into existence. Rounding out the speaker schedule was Terence Dickinson whose presentation, "Exploring the Universe through Wide-Angle Photography," drew a standing ovation from the audience.

The last 30 minutes or so were used to distribute more than $10,000 in prizes to more than 40 lucky winners. The grand prize was an 8-inch LX200 telescope donated by Meade Instruments. Second prize was a set of Panoptic eyepieces donated by Al Nagler and TeleVue Optics. In all, about one in 28 people went home with prizes, valued from $20 to $2,800.

The 1999 NEAF will be, for the first time, a two-day affair held at the United States Military Academy at West Point, New York. The scheduled dates are Saturday and Sunday, May 1–2.

The Rockland Astronomy Club wishes to thank the many participants who have supported the NEAF for the last seven years. We promise that next year's show will be the best yet.

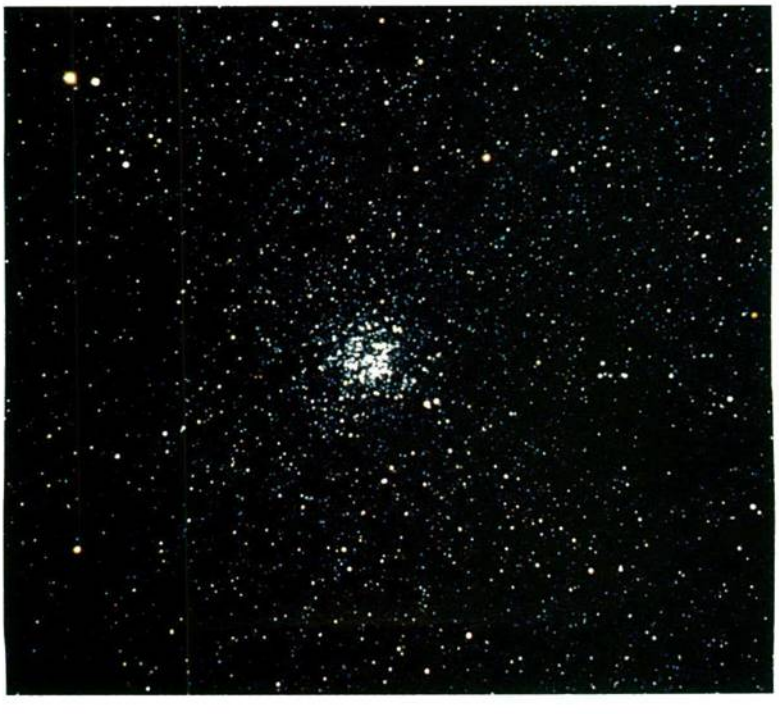
Don Urban is an avid amateur astronomer and a member of the Rockland Astronomy Club.



Sunspots Grace the Solar Limb

GORDON GARCIA

(130mm refractor at f/86, Kodak Tech Pan 2415 film, 1/1000-second exposure taken March 21, 1998)



The Wild Duck Cluster in Scutum

LEE C. COOMBS

(10-inch f/5 reflector, Ektachrome P 1600 film, 15-minute exposure)

Orion Highlights the Horsehead Nebula (B33)

BILL AND SALLY FLETCHER

(8-inch f/1.5 Schmidt Camera, Tech Pan 2415 film, composite of 14-minute red, 54-minute green, and 64-minute blue exposures)

The Distant Galaxy Group around NGC 507

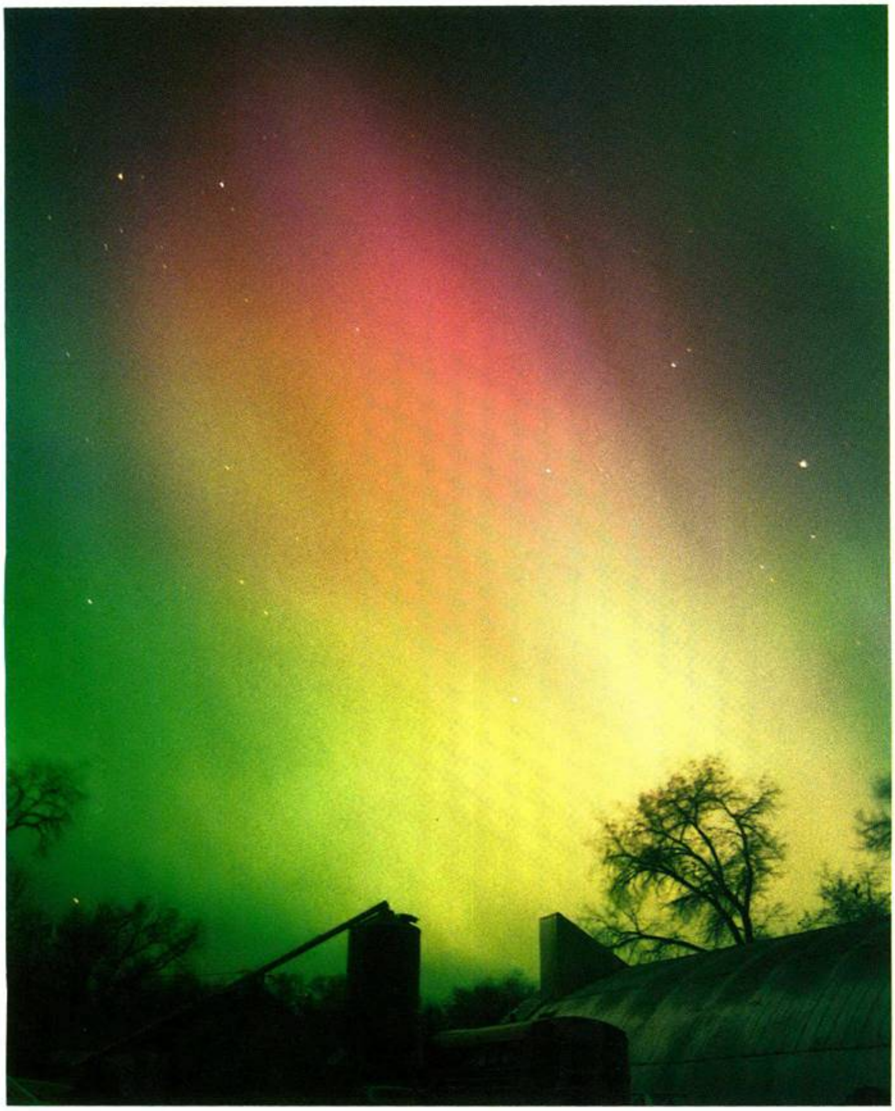
CHUCK VAUGHN

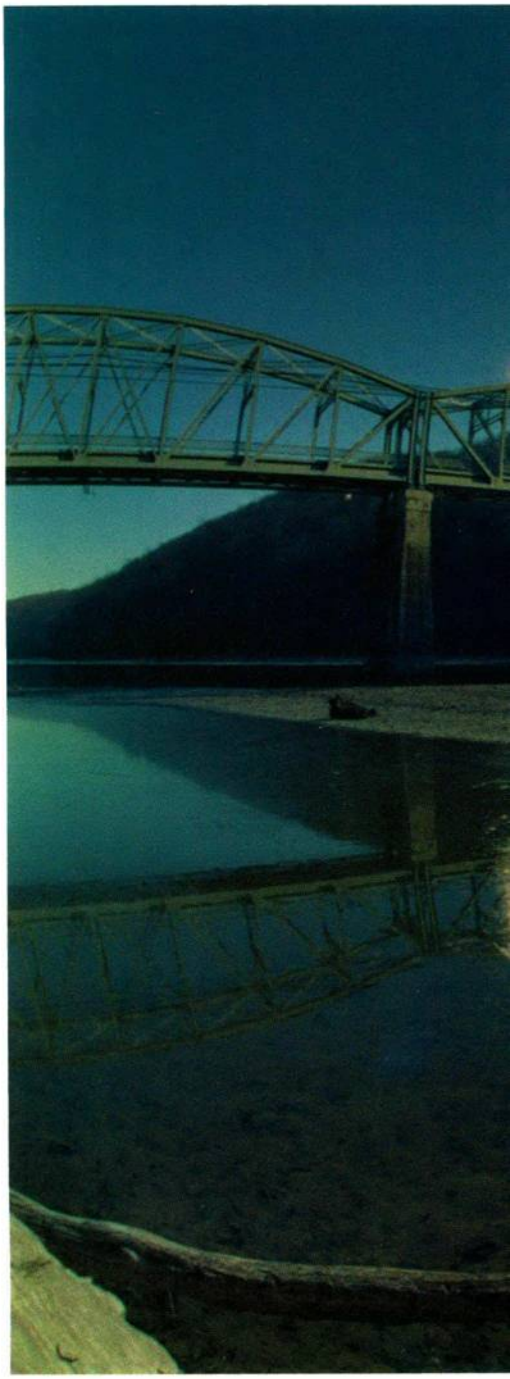
(12.5-inch f/9 Ritchey-Chrétien scope, Tech Pan 2415 film, 150-minute exposure)

Auroral Surge

JAY BRAUSCH

(28mm lens at f/3.5, Fujicolor Super G800 film, 30-second exposure taken May 3, 1998)

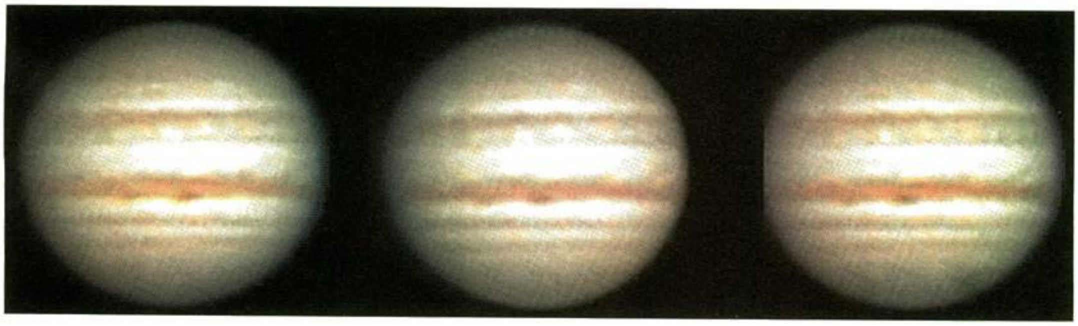




Solstice at Loch Raven Reservoir

DAVID HOBBY

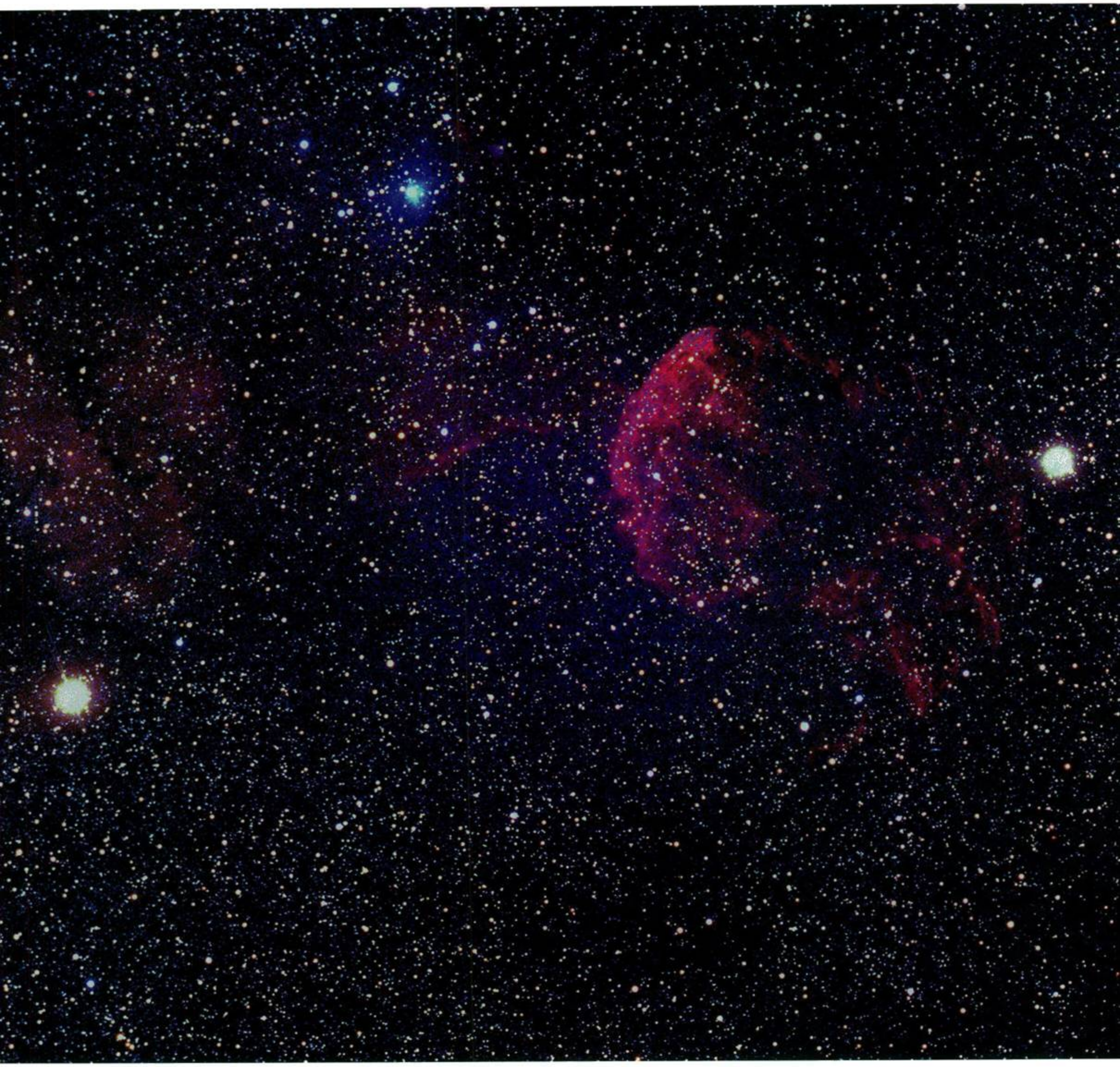
(16mm f/3.5 fish-eye lens, Fujicolor 100 film, multiple exposures at 52-minute intervals beginning at sunrise, December 21, 1997; all images shot at $\frac{1}{8,000}$-second at f/32 except noon shot [$\frac{1}{125}$-second exposure at f/16], and last shot [$\frac{1}{125}$-second exposure at f/8])



Jupiter Rotates

DON PARKER

(16-inch SCT at f/22, Lynxx PC CCD camera, composite of 5½-second blue, 2¾-second green, and 2¼-second red exposures taken June 9, 1998)



Inside a Supernova Remnant

CARL AND CHRIS WEBER

(6-inch f/7 refractor, 120 format Kodak Pro 400 PPF film, composite of two 50-minute exposures) IC 443 (right), home of pulsar 0611+22, is the remnant of an ancient supernova explosion. The gases are still expanding and give it a wreath-like appearance. VDB 75 is the bright blue reflection nebula near the top center of the photo, and IC 444 is the fainter nebulosity on the left. Note the faint traces of an unnamed reflection nebula bridging the gap between the two brighter nebulae.

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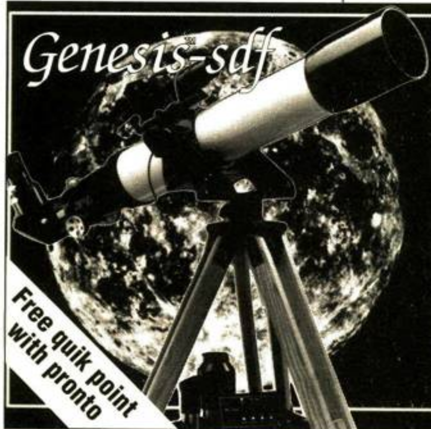

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Photo of Horsehead Nebula taken with Pronto by Ralph Sieger

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The Great Nebula in Orion (M42). A composite 60-minute exposure by Jason Ware on Fuji HG400 film with the Meade Model 152ED 6" f/9 *ED* Apochromatic Refractor.

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